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SEC DONOHUE

FINAL BASELINE RISK ASSESSMENT REPORT
ENVIRONMENTAL EVALUATION

HI-MILL MANUFACTURING RI/FS OVERSIGHT
HIGHLAND, MICHIGAN

DECEMBER 1992

Prepared for:

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DECEMBER 1992

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BASELINE RISK ASSESSMENT REPORT--
ENVIRONMENTAL EVALUATION

Baseline Risk Assessment for the Hi-Mill Manufacturing Site

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LIST OF ACRONYMS

CLP	Contract Laboratory Program
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
ER-L	Effects Range-Low
ER-M	Effects Range-Median
GC	Gas Chromatography
IDL	Instrument Detection Limit
MDNR	Michigan Department of Natural Resources
RI	Remedial Investigation
TAL	Target Analyte List
TCE	Trichloroethylene
TCL	Target Compound List
TIC	Tentatively Identified Compounds
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

1.0 INTRODUCTION

This report provides an ecological assessment for the Hi-Mill Superfund site near Highland, Michigan. It is based on personal observations, survey results and documents available through August, 1992. This assessment supplements the remedial investigation (RI) report (Geraghty and Miller 1992) and human health evaluation report (Life Systems 1992) prepared for this Superfund site.

1.1 Objectives of the Ecological Assessment

The objectives of this report are as follows:

1. Assemble available ecological information on the site into an environmental evaluation report.
2. Characterize the biological resources of the site and adjacent habitats.
3. Identify actual and potential impacts associated with release of hazardous substances from the site.

The first two objectives will be met by summarizing and discussing findings of studies conducted at the site and readily available information on ecological conditions of the area of southeastern Michigan where the site is located. Where possible, references to relevant tables and figures in the RI Report are provided for reader convenience.

The third objective will be met by performing a retrospective ecological assessment (USEPA 1991a) according to current U.S. Environmental Protection Agency (USEPA) guidance (USEPA 1991a, 1989b,c). For purposes of this report, this is defined as using information from existing site studies and toxicological information from the literature to characterize ecological impacts and potential risks that may have resulted from past manufacturing and waste management activities at the Hi-Mill site.

1.2 Scope of the Ecological Assessment

The scope of this assessment is limited to characterizing the environmental setting, including an ecological inventory and identifying impacts and potential risks associated with release of hazardous substance from the site under the no-action alternative. The no-action alternative occurs in the absence of any remedial actions (including institutional controls) to control or mitigate releases or exposures. The scope of the assessment does not include the following:

- An evaluation of ecological impacts of remedial alternatives
- Establishment of clean-up goals and remedial action objectives for ecological resources

1.3 Organization of This Report

Including this Introduction, this report includes nine sections and two appendices. Section 2.0 describes the site and history of activities. An ecological inventory is provided for the site in Section 3.0. Section 4.0

provides an analysis of site contamination and identifies contaminants of potential ecological concern. Section 5.0 provides an exposure assessment for ecological resources potentially exposed to contaminants at the site. Section 6.0 characterizes impacts and potential risks to ecological resources. Section 7.0 summarizes uncertainties in the assessment. Section 8.0 provides conclusions and Section 9.0 provides references used in the ecological assessment.

Appendix 1 contains exposure point concentrations for ecologically important environmental media. Appendix 2 contains summaries of ecotoxicological properties of chemicals of greatest ecological concern at this site.

2.0 SITE DESCRIPTION AND HISTORY

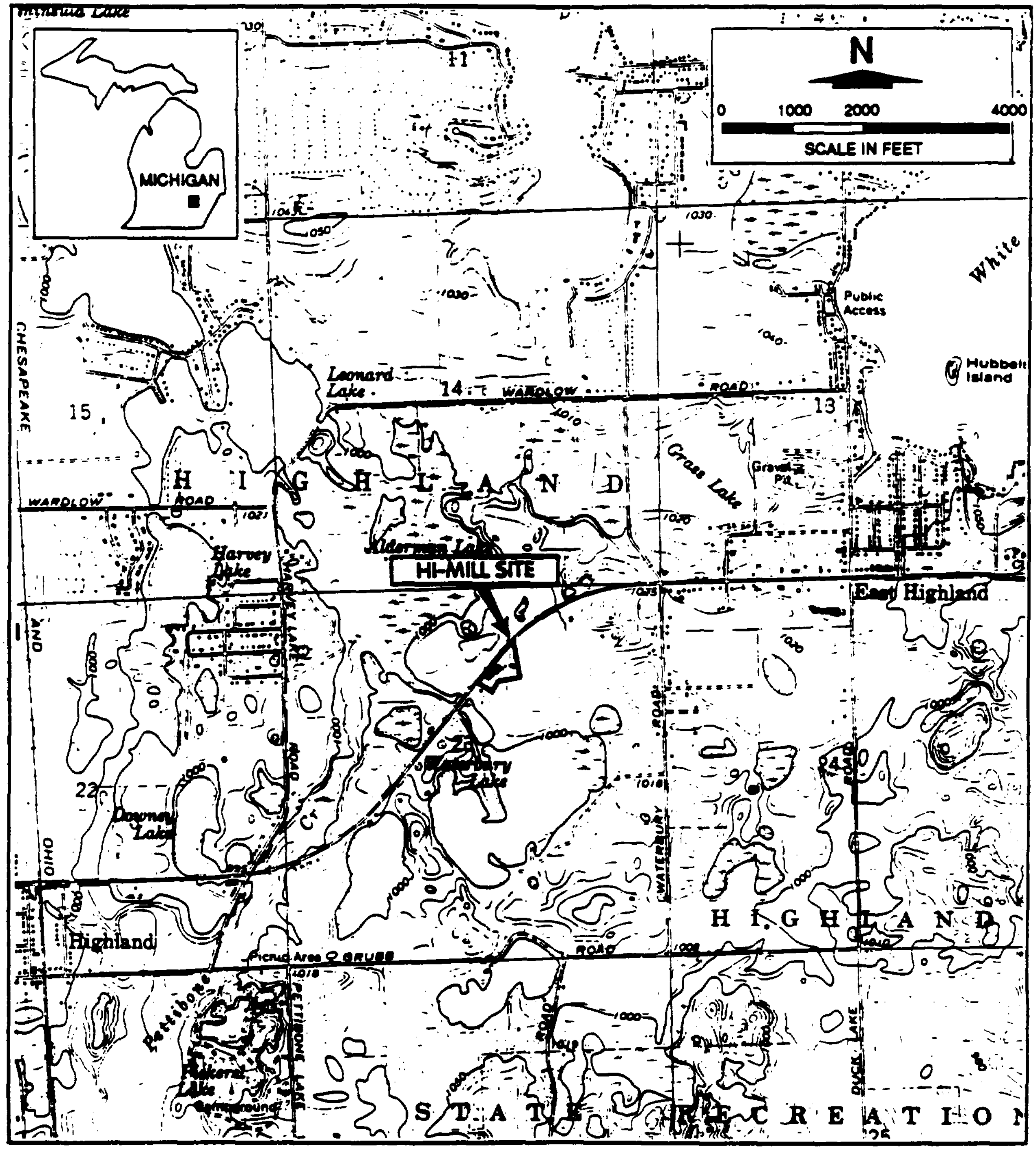
2.1 Site Description

The Hi-Mill site (Figure 2-1) is a parcel of approximately 4.5 acres located immediately southeast of Highland Road (M-59) about 1.5 miles east of the town of Highland, in Oakland County, Michigan. A detailed description of the Hi-Mill site, including a detailed site history and site maps, is provided in the RI reports for this site (Geraghty and Miller 1992). A brief summary of information that is relevant to this assessment is presented below.

2.2 Site History

The Hi-Mill Manufacturing Company currently operates a metal parts fabrication plant at the site. The site layout is shown in Figure 2-2. Copper, aluminum and brass tubing parts and fittings have been manufactured at the plant since 1946. Soldering operations at the plant have used silver solder or aluminum bar brazing. Cleaning and pickling operations used nitric and sulfuric acids and degreasing operations used trichloroethylene (TCE). Trichloroethylene is stored on-site in an outdoor storage tank. Wastes from these operations were formerly disposed of in two on-site lagoons, which have been drained, filled and are now vegetated.

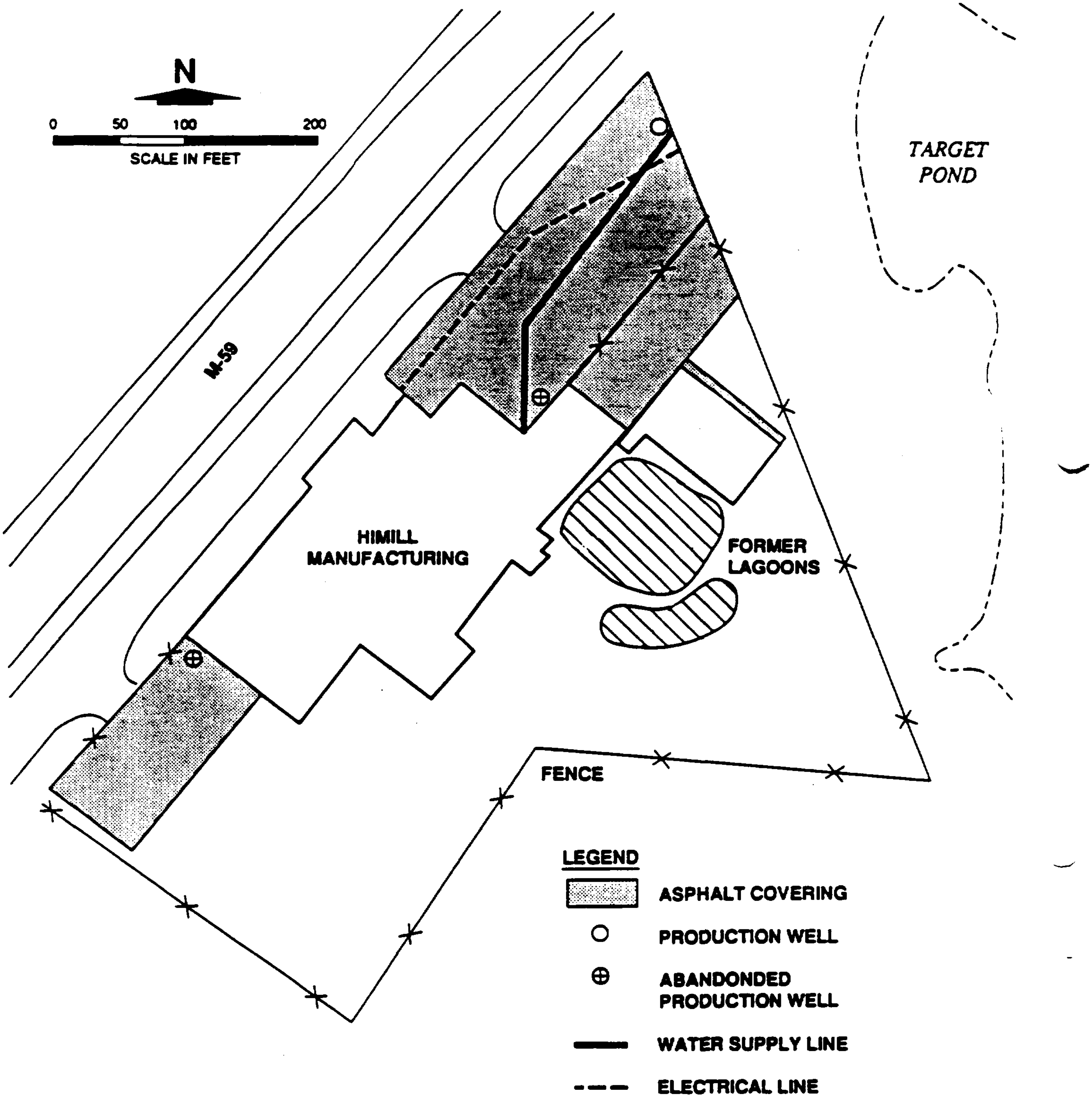
Based on the Hi-Mill site operations, the chemicals expected to be of potential ecological concern at the site are the volatile organics that are used in degreasing operations and their degradation products and the inorganics used in fabrication processes. The contaminant pathways of potential concern are contaminated soil, surface runoff from contaminated soil and migration of contaminants into and through the groundwater.



SOURCE: USGS 7.5 Minute Topographic Map, HIGHLAND, MICHIGAN Quadrangle, 1983

Adapted from Geraghty & Miller 1990.

FIGURE 2-1 LOCATION OF HI-MILL SITE



Adapted from Geraghty & Miller 1990.

FIGURE 2-2 OVERVIEW OF THE HI-MILL SITE

3.0 ECOLOGICAL INVENTORY

The following ecological surveys were performed in September, 1991 at the Hi-Mill site as part of Phase II data collection activities:

- Vascular plant survey
- Terrestrial vertebrate and invertebrate survey
- Phytoplankton survey
- Zooplankton survey
- Benthic macroinvertebrate survey

An index to the locations of the tabular and graphical results of these surveys in Appendix R of the RI Report (Geraghty and Miller 1992) is presented in Table 3-1. A brief summary of the results of these surveys is provided in the following sections.

A survey of plankton and benthic macroinvertebrates was conducted by the Michigan Department of Natural Resources (MDNR) in 1984.

3.1 Terrestrial Plant Communities

The southeastern portion of the lower Michigan peninsula is located in the temperate deciduous forest biome (Baker 1983). This area is characterized by three major forest communities (Barnes and Wagner 1981):

- Oak-hickory community
- Beech-sugar maple community
- Deciduous swamp community

A terrestrial vegetation survey was conducted in September, 1991. The area covered by this survey is shown in Figure 3 of Appendix R to the RI Report (Geraghty and Miller 1992).

3.1.1 Vegetation On Site

Although the site is located in a rural area, vegetation is highly disturbed as a result of current and historical manufacturing and waste disposal activities. Two types of plant communities dominate the terrestrial vegetation on site:

- Shrub community
- Old field community

The shrub community dominates by covering 52 percent of the site, while the old field community covers 18 percent of the property. Other areas of the site are mowed or covered by buildings and parking lots. Figure 6 of Appendix R in the RI Report shows locations of major plant communities in the survey area on an aerial photograph (Geraghty and Miller 1992).

The shrub community occupies most of the Hi-Mill site south of the buildings along Rt. 59. The old field community occurs as isolated pockets interspersed throughout the shrub community. The shrub community is dominated by middle-to-late successional species of woody and herbaceous vegetation, while the old

TABLE 3-1 SUMMARY OF ECOLOGICAL SURVEYS AT THE HI-MILL SITE

Survey Type	Table[a]	Figure[a]
Terrestrial Vegetation	4;5;6	6; Appendix A
Wetland Vegetation	5;7;8	6; Appendix A
Terrestrial Wildlife	9;10	
Waterfowl and Shorebirds	9;10	
Wetland and Open Water Wildlife	9;10	
Phytoplankton	13; Appendix B, Table 2	4;8; Appendix B, Figures 1-7
Zooplankton	14; Appendix B, Table 3	4;9
Benthic Macroinvertebrates	15; Appendix B, Table 4	4;10

(a) Ecological inventory/assessment report, Phase II remedial investigation, Appendix R, Geraghty and Miller (1992).

field community consists of early-to-middle successional species of herbaceous vegetation. The shrub community is being invaded by a variety of tree species, with quaking aspen (Populus tremuloides) and red maple (Acer rubrum)in greatest relative abundance. Eastern red cedar (Juniperus virginiana) is the only tree species observed in the old field community (Geraghty and Miller 1992).

3.1.2 Vegetation in Nearby Areas

Vegetation adjacent to the site can be grouped into three types:

- Relatively undisturbed forest and wetland communities associated with the MDNR's Highland State Recreation Area and Waterbury Lake
- Wetland vegetation associated with Target Pond
- Herbaceous vegetation associated with Michigan State Route 59

Only portions of the wetland vegetation associated with Target Pond and Waterbury Lake were included in the September, 1991 vegetation survey. Wetland vegetation in unsurveyed areas around Target Pond and Waterbury Lake is likely to be similar to that in areas included in the survey.

Although not included in the survey, terrestrial vegetation in upland areas unaffected by the site is likely to be dominated by species similar to those found in the shrub and old field communities at the site. Plant species identified in the wetland vegetation survey discussed in the next section are likely to be representative of species in plant communities that occur in other off-site areas adjacent to the site that were not included in the survey.

3.2 Wetlands

Areas of wetland vegetation were included in the September, 1991 inventory. Although a formal wetland delineation has not been performed at this site, nearby wetlands have been classified as part of the U.S. Fish and Wildlife Service (USFWS) wetlands inventory (Geraghty and Miller 1992). The following types of wetlands were identified in this inventory:

- Palustrine, emergent vegetation with a semipermanent water regime (PEMF): The background pond, the north arm of Waterbury Lake, the margins of Waterbury Lake and the majority of Target Pond

- Lacustrine, littoral vegetation with a permanent open water regime (L2OWH): The center portion of Waterbury Lake

- Palustrine, forested vegetation with a saturated, semipermanent or seasonal water regime (PROY): The northeast portion of Target Pond

Wetlands associated with Target Pond are located generally along the east side of the site. Wetland vegetation is also located along the north arm of Waterbury Lake and Waterbury Lake south and southwest of the site. Remnants of wetland vegetation also occur on site in the area where the former lagoon was located behind the main manufacturing building and south of the parking area on the west end of the site.

Two types of wetland communities (emergent and forested) were identified in the September, 1991 survey. Emergent wetland communities were located in the following areas:

- Northeast of the site where Target Pond meets Rt. M-59
- Southeast of the site at the corner of the Hi-Mill fence and Target Pond
- South of the parking lot at the west end of the buildings on site
- South of the main building where the former lagoon was located
- Along the margins of the north arm of Waterbury Lake and Waterbury Lake

Forested wetland areas that include swamp white oak (Quercus bicolor, American elm (Ulmus americana), black willow (Salix nigra)and other tree species occur in smaller areas on the north and west edges of Target Pond.

3.3 Aquatic Vegetation

Information on submerged vascular plants is limited for this site. Only duckweed (Lemna), pond weed (Potamogeton) and Elodea (Anacharis) were recorded in Target Pond during 1984 MDNR survey. Several species of filamentous algae (e.g., Spirogyra, Oscillatoria) were also observed in Target Pond in 1984, Periphyton was noted to be abundant. No information is available on submerged vascular plants in any of the other water bodies in the vicinity of the site.

3.4 Wildlife

A qualitative survey of animals occurring in the vicinity of the site and Waterbury Lake (the background location) was conducted in 1991. Results of the survey are presented in Table 9 of Appendix R in the RI Report. A variety of birds, mammals and invertebrates were observed in the upland and wetland habitats associated with the two areas. Frogs were observed in and around Waterbury Lake, but not Target Pond. Table 10 of Appendix R to the RI Report contains an extensive list (unreferenced) of many birds, mammals, reptiles and amphibians that may occur in the vicinity of the site, but have not been observed.

3.5 Aquatic Communities

Surveys of phytoplankton, zooplankton and benthic macroinvertebrates were completed at two stations in Waterbury Lake and one to six stations in Target Pond on September 19, 1991. Waterbury Lake was selected to represent background conditions during this survey. Appendix B to RI Report Appendix R contains the aquatic survey of Target Pond and Waterbury Lake. Due to possible mislabeled tables and figures, it is difficult to determine exactly how many samples were collected from the two water bodies.

The September, 1991 aquatic biology survey suffered from three major limitations:

- Only two locations were sampled in Waterbury Lake

- No effort was made to characterize fish populations at any location near the Hi-Mill site

- A minimal volume of surface water was sampled for characterizing zooplankton communities

Due to the small volumes of water sampled, only limited numbers of zooplankton were collected. This small sample results in significant uncertainty in characterizing the true zooplankton communities in the two water bodies.

The September, 1991 survey should be considered a minimal effort, at best. The survey can be used to characterize qualitatively only overall conditions in Target Pond. Too few samples were collected to establish a location-specific relationship between chemical concentration levels in sediment and surface water in areas likely to receive runoff from the Hi-Mill site and biota at survey locations. The results of these survey are summarized below.

3.5.1 Target Pond

3.5.1.1 Phytoplankton

A diverse assemblage of phytoplankton species was present at the time of sampling. Major groups, golden algae and diatoms (Chrysophyta), cryptomonads (Cryptophyta), green algae (Chlorophyta), blue-green algae (Cyanophyta) and dinoflagellates (Pyrrophyta) were well represented. Detailed results of the survey are presented in section 3.2, Table 2 and Figures 2 through 7 of Appendix B to RI Report Appendix R.

3.5.1.2 Zooplankton

Zooplankton apparently were only sampled at one location in Target Pond. The zooplankton community contains species of cladocerans and copepods which are tolerant of stressed conditions, based on sparseness and food preferences. The most abundant species, Bosmina longirostris and Chydorus sphericus are filter and raptorial feeders that are highly resistant to algal toxins and harsh ecological conditions. At least one predatory copepod (Diaptomus) is represented in the sample, indicating that at least a minimal zooplankton food web is present.

Zooplankton (particularly Daphnia) were noted to be abundant in the water column in Target Pond during the 1984 MDNR survey.

3.5.1.3 Benthic Macroinvertebrates

Relatively low numbers of macroinvertebrates were collected at each location in Target Pond in September, 1991. Overall, midges (Chironomidae), caddisflies (Trichoptera) and snails (Gastropoda) were most abundant. The mix of species present in this community indicates average water quality conditions.

Pollution tolerant midges were the only benthic macroinvertebrates found in Target Pond during the 1984 MDNR survey.

3.5.2 Waterbury Lake

3.5.2.1 Phytoplankton

The two samples analyzed from Waterbury Lake suggest that a less diverse phytoplankton community is present compared to Target Pond. In addition, the number of organisms per sample is about a half to a third of that observed in Target Pond. The only species that differ between the two water bodies are in the Pyrrophyta, with *Ceratium* sp. in Target Pond and *Peridinium* sp. in Waterbury Lake.

3.5.2.2 Zooplankton

Only 32 individual zooplankton organisms (six species) were collected from Waterbury Lake, compared to 465 (nine species) from Target Pond. Both cladocerans and copepods were represented in the two samples from Waterbury Lake. A mix of feeding behaviors are represented in the zooplankton species, suggesting that a zooplankton food web is present in Waterbury Lake.

3.5.2.3 Benthic Macroinvertebrates

No benthic macroinvertebrates were in samples from the two locations in Waterbury Lake. This sample size is too small to conclude that there is no benthic macroinvertebrate community present in this lake.

3.5.3 Background Pond

Biological sampling was not performed at the background pond location.

3.6 Endangered and Threatened Species

Correspondence with the USFWS and the MDNR Endangered Species Coordinator is cited in the RI Report that indicates that there are no threatened or endangered species within one mile of the Hi-Mill site (Geraghty and Miller 1992).

3.7 Summary of Ecological Inventory

3.7.1 Terrestrial Vegetation and Wildlife

Upland vegetation on the site and in nearby areas is typical of disturbed areas undergoing succession following disturbance. A variety of animals were observed during a cursory survey, and numerous species are likely to be present, but have not been observed.

3.7.2 Wetlands

Wetland vegetation is present around Target Pond and Waterbury Lake. Wetlands are located adjacent to the site where they may be subject to exposure to contaminants in surface water runoff.

3.7.3 Aquatic Communities

Target Pond and Waterbury Lake are very shallow water bodies. Water level fluctuations are severe in Target Pond, but less so in Waterbury Lake. The shallow nature of these waterbodies suggests that they may both be subject to freezing over most of their depth during winter. These factors may represent significant stress factors for aquatic populations.

Conductivity is generally two to six times higher in Target Pond than in Waterbury Lake. Highest conductivity occurs at station TP-04 near the Hi-Mill site. This may indicate a release of inorganic constituents to Target Pond in the vicinity of this sample location.

3.7.3.1 Target Pond

Target Pond contains planktonic and benthic communities which do not indicate severely polluted conditions. Too few samples were collected for anything more that a qualitative evaluation of overall water quality conditions.

Although survey data are minimal, both communities are likely to represent food supplies sufficient to support fish populations. A dead mud minnow was observed near the site of Hi-Mill outlet from the parking lot and roof runoff drainage system during the 1984 MDNR survey. Information is not sufficient to rule out the possibility that a fish community is present in Target Pond.

In summary, the aquatic survey performed in September, 1991 is not sufficient to determine whether some areas of Target Pond are being impacted adversely from runoff from the Hi-Mill site.

3.7.3.2 Waterbury Lake

Waterbury Lake is significantly larger than Target Pond, yet only two samples are available to characterize aquatic biological conditions. The results of the September, 1991 survey are only sufficient for a qualitative characterization of the phytoplankton and zooplankton communities, both of which are present and generally similar, though less abundant, to those in Target Pond.

No benthic organisms were detected in the two sediment samples collected from Waterbury Lake. Since this represents a very small area of the entire lake, it cannot be concluded that there is no benthic macroinvertebrate community present in Waterbury Lake.

Apparently no systematic survey has been conducted in Waterbury Lake to characterize fish communities. Minnows were observed in this lake during the 1984 MDNR survey. The planktonic community in Waterbury Lake may be capable of supporting a fish community. This is an unresolved issue at this site.

The general lower abundance and diversity in aquatic organisms in Waterbury Lake suggested by the September, 1991 survey indicates that the lake may not represent background conditions. If the aquatic biota are depauperate in this lake, it may indicate that Waterbury Lake may be impacted by runoff or groundwater contamination from the Hi-Mill site that has not been detected by site monitoring and characterization to date.

4.0 CONTAMINANT ANALYSIS

Chemicals present at the site as a result of historical manufacturing and waste disposal activities may pose direct or indirect toxic effects to exposed organisms. These effects may lead to ecological impacts at the population, community and ecosystem levels. For purposes of this assessment, chemicals with these characteristics are referred to as contaminants of ecological concern. This section identifies contaminants of potential ecological concern from results of sampling and analysis conducted as part of the RI for the Hi-Mill site. Contaminants of ecological concern are identified in Section 7.0.

A summary of the analytical data available for the Hi-Mill site and a description of the procedures used to identify chemicals of potential ecological concern from these data are presented below.

4.1 Summary of Available Data

Remedial Investigation field activities were conducted at the Hi-Mill site by Techna Corporation from January 29 to March 29, 1990 (Phase I). In order to further characterize the nature and extent of contamination at the site, a second round of sampling (Phase II) was performed by Geraghty and Miller from November 21, 1991 to February 19, 1992 (Geraghty and Miller 1992). Samples of soil, surface water, groundwater and sediments were collected on and near the site and analyzed for compounds on USEPA's Target Compound List (TCL) and Target Analyte List (TAL) according to USEPA Contract Laboratory Program (CLP) protocols (USEPA 1988a,1988b). A summary of the sampling and analysis performed during Phase I and Phase II is provided below. The sampling locations are identified in Figures 4-1 and 4-2 and in the RI Report.

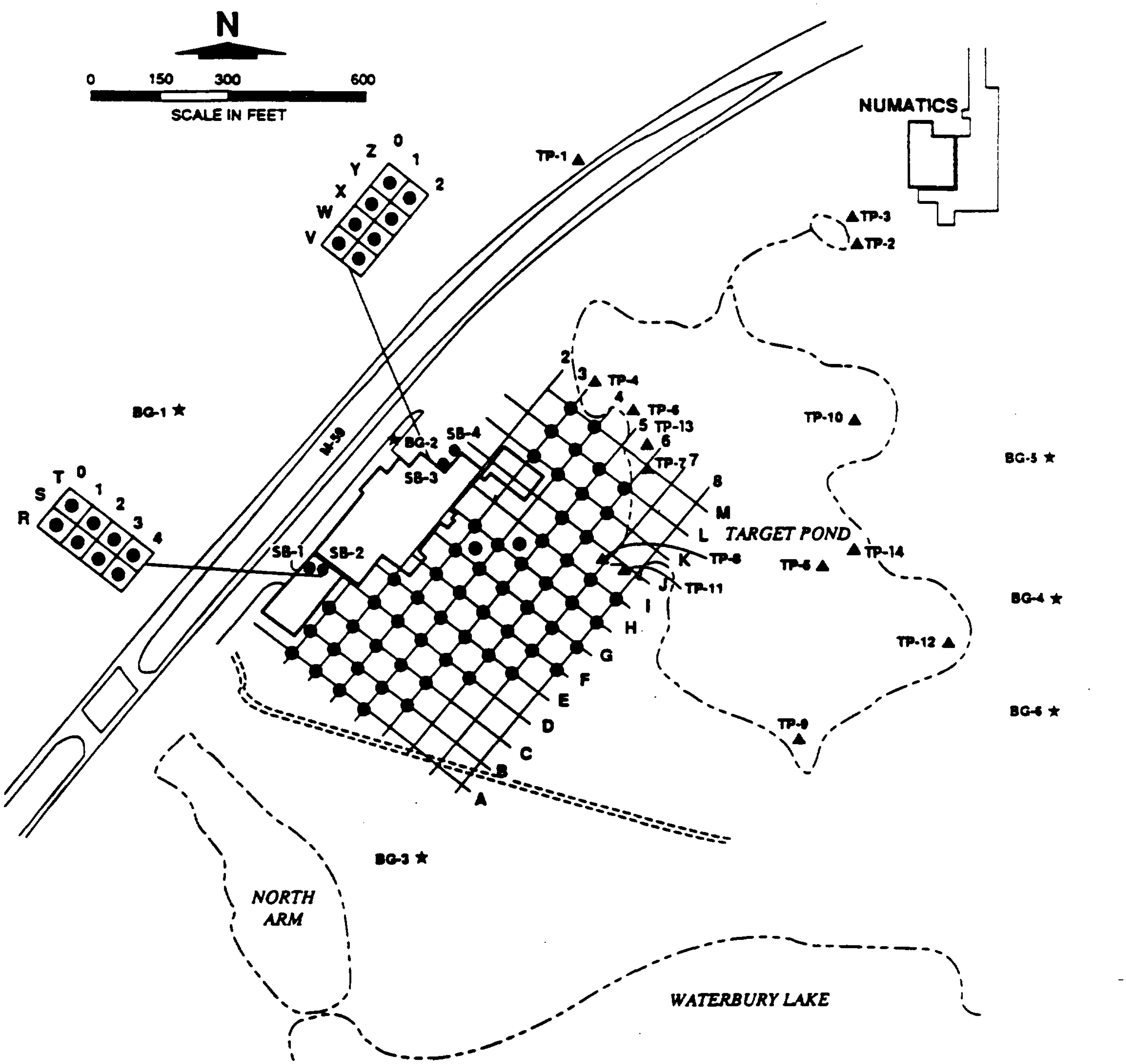
4.1.1 Phase I Data

Soil

A total of 271 soil samples were collected from on-site locations. These included both surface (0 to 1 foot deep) and subsurface (1.5 to 16.5 feet deep) samples and were collected from soil borings and monitoring wells dug in the areas beneath the parking lots north and south of the Hi-Mill buildings and the area behind the buildings. Analyses for "short list" metals (metals selected by Techna (1990) expected to be present based on Hi-Mill site activities; aluminum, chromium, copper, nickel, silver and zinc) were performed on 176 samples, including 15 field duplicates. Twenty-six samples, including 2 field duplicates, were analyzed for all TAL chemicals; 54 samples, including 5 field duplicates, were analyzed for TCL volatile compounds and 15 samples, including 2 field duplicates were analyzed for TCL semivolatiles. Ten background soil samples were collected and analyzed for TAL chemicals and TCL compounds.

Groundwater

Groundwater samples were collected from 31 monitoring wells on and near the site. All samples were analyzed for dissolved short list metals and 8 samples, including 1 field duplicate, were analyzed for dissolved TAL metals. Twenty-nine samples, including 3 field duplicates, were analyzed for TCL



LEGEND

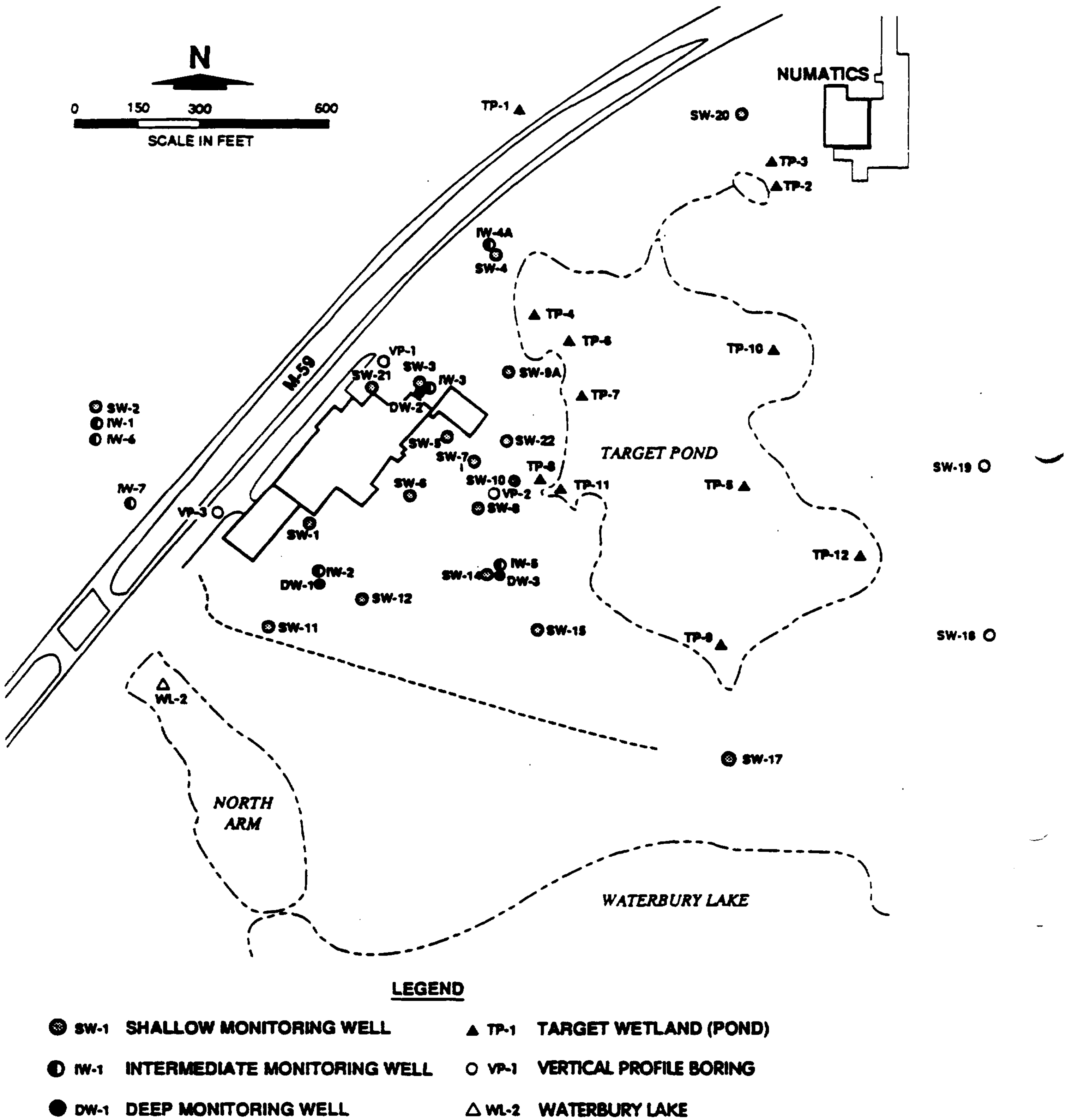
BG-1 ★ BACKGROUND SOIL

TP-1 ▲ TARGET WETLANDS (POND) SEDIMENT

● SOIL BORING

Adapted from Geraghty & Miller 1990.

FIGURE 4-1 SOIL AND SEDIMENT SAMPLING LOCATIONS



Adapted from Geraghty & Miller 1990.

FIGURE 4-2 GROUNDWATER AND SURFACE WATER SAMPLING LOCATIONS volatiles; 5 samples, including 1 field duplicate, were analyzed for TCL semivolatiles; and 30 samples, including 3 field duplicates were analyzed for ammonia-nitrogen and nitrate + nitrite.

Surface Water

Eleven surface water samples were collected from Target Pond and two samples were collected from Waterbury Lake. Four background samples were collected from a nearby pond. Samples were analyzed for the short list metals and chromium VI. Five samples were analyzed for all TAL chemicals and nine were analyzed for ammonia-nitrogen and nitrate + nitrite.

Sediments

Twenty-four sediment samples were collected, twenty-one from Target Pond and three from Waterbury Lake. In addition, four background sediment samples were collected from a nearby pond. Samples were analyzed for the short list metals and chromium VI. Five samples were analyzed for all TAL chemicals.

4.1.2 Phase II Data

Field Gas Chromatography (GC) analyses of soil and groundwater samples from around the Hi-Mill plant were performed during the Phase II investigation. The data generated by these analyses were used for screening purposes and were not used for quantitative evaluations. Only samples of environmental media analyzed in accordance with CLP protocols are described below.

Soil

Twelve subsurface (7.5 to 117 feet deep) soil samples were collected from soil borings and monitoring wells and analyzed for TAL chemicals and TCL volatiles.

Groundwater

Thirty-four groundwater samples were collected from monitoring wells on and near the Hi-Mill site and analyzed for TCL volatiles. Thirty of these samples were analyzed for TAL dissolved metals, and six of these samples were also analyzed for total metals.

Sediments

Four sediment samples from Target Pond and two from Waterbury Lake were analyzed for all TAL chemicals except cyanide.

Surface Water

No surface water samples were collected for chemical analysis during Phase II investigations.

4.2 Data Quality Evaluation

During the RI investigations numerous environmental samples were analyzed by field GC. Only data generated by laboratories following CLP or CLP-equivalent protocols were used for quantitative evaluations. Field GC data were used only for qualitative assessment.

The data from both Phases were validated by Geraghty and Miller according to guidance provided by USEPA (1988). Data were qualified either by the laboratory or by the validator according to USEPA guidance, and data were used in the RA as follows:

Data which were considered unreliable due to quality control problems were qualified with an "R" and were not used.

Chemicals which were analyzed for but were not detected were qualified with a "U." The "U" qualifier represents the Contract Required Quantitation Limit (CRQL) or Contract Required Detection Limit (CRDL) adjusted for any sample matrix or preparation requirements for analysis. In addition, samples associated with contaminated blanks were "U" qualified, if the concentration in the sample was less than 10 times the blank concentration for common laboratory contaminants (methylene chloride, acetone, 2-butanone), or less than 5 times the blank concentration for other chemicals, in accordance with USEPA (1991b) guidance. These values were used as nondetects.

Any detected value for an organic chemical which was detected at greater than 10 times or 5 times the concentration in the associated blank was qualified with a "B." These values were used as if they were unqualified.

Any sample values with minor deviations from CLP requirements for holding times, analytical spikes, duplicates or other quality control parameters were considered estimated values and were coded with a "J." Sample values less than the CRQL were also "J" qualified. These values were used as if they were unqualified, as recommended by USEPA (1989).

Any detected value for an inorganic chemical reported as less than the CRDL but greater than the Instrument Detection Limit (IDL) was qualified with a "B." These values were used in the risk assessment as if they were unqualified.

4.3 Selection of Chemicals of Potential Ecological Concern

Monitoring data from the Hi-Mill site were organized to form a database for evaluation. During this evaluation a number of chemicals were eliminated for various reasons. The remaining chemicals are the chemicals of potential ecological concern for the Hi-Mill site. The approach is described below.

4.3.1 Chemicals Never Detected

Any chemical which was never detected in any medium sampled at Hi-Mill (i.e., qualified by a "U" in every sample) was eliminated from consideration as a chemical of potential ecological concern, since there is no evidence that the chemical is present in these media. The chemicals eliminated because they were not detected are listed in Table 4-1.

Exclusion of a chemical because it was never detected introduces some uncertainty into the assessment. This is especially true if the analytical detection limit for the chemical was sufficiently high (i.e., insensitive) that an ecological effect might occur from chemicals present on-site at concentration levels equal to or less than the detection limit. The uncertainty introduced by exclusion of never-detected chemicals is discussed in Section 8.2.

TABLE 4-1 CHEMICALS NEVER DETECTED IN ANY MEDIUM AT HI-MILL

Chemical Name	Chemical Name	Chemical Name
Acenaphthene	Chloronaphthalene, 2-	Fluoranthene
Acenaphthylene	Chlorophenol, 2-	Fluorene
Aldrin	Chlorophenyl-phenylether, 4-	Gamma Chlordane
Alpha Chlordane	Chromium (VI)	Gamma-BHC
Alpha-BHC	Chrysene	Heptachlor
Anthracene	DDD, 4,4-	Heptachlor epoxide
Aroclor-1016	DDE, 4,4-	Hexachlorobenzene
Aroclor-1221	DDT, 4,4-	Hexachlorobutadiene
Aroclor-1232	Delta-BHC	Hexachlorocyclopentadiene
Aroclor-1242	Di-n-octylphthalate	Hexachloroethane
Aroclor-1248	Dibenz(a,h)anthracene	Hexanone, 2-
Aroclor-1254	Dibenzofuran	Indeno(1,2,3-cd)pyrene
Aroclor-1260	Dibromochloromethane	Isophorone
Benzene	Dichlorobenzene, 1,2-	Methoxychlor
Benzo(a)anthracene	Dichlorobenzene, 1,3-	Methylnaphthalene, 2-
Benzo(a)pyrene	Dichlorobenzene, 1,4-	Methylphenol, 2-
Benzo(b)fluoranthene	Dichlorobenzidine, 3,3'-	Methylphenol, 4-
Benzo(g,h,i)perylene	Dichloroethane, 1,2-	N-Nitroso-di-n-propylamine
Benzo(k)fluoranthene	Dichloroethene, 1,1-	N-Nitrosodiphenylamine
Benzoic acid	Dichlorophenol, 2,4-	Naphthalene
Benzyl alcohol	Dichloropropane, 1,2-	Nitroaniline, 2-
Beta-BHC	Dichloropropene, cis-1,3-	Nitroaniline, 3-
Bis(2-chloroethoxy)methane	Dichloropropene, trans-1,3-	Nitroaniline, 4-
Bis(2-chloroethyl)ether	Dieldrin	Nitrobenzene
Bis(2-chloroisopropyl)ether	Diethylphthalate	Nitrophenol, 2-
Bromoform	Dimethylphenol, 2,4-	Nitrophenol, 4-
Bromomethane	Dimethylphthalate	Pentachlorophenol
Bromophenyl-phenylether, 4-	Dinitro-2-methylphenol, 4,6-	Phenanthrene
Butylbenzylphthalate	Dinitrophenol, 2,4-	Phenol
Carbon disulfide	Dinitrotoluene, 2,4-	Pyrene
Carbon tetrachloride	Dinitrotoluene, 2,6-	Styrene
Chloro-3-methylphenol	Endosulfan I	Thallium
Chloroaniline, 4-	Endosulfan II	Toxaphene
Chloroethane	Endosulfan sulfate	Trichlorobenzene, 1,2,4-
Chloroethyl vinyl ether, 2-	Endrin	Trichlorophenol, 2,4,5-
Chloromethane	Endrin ketone	Trichlorophenol, 2,4,6-

4.3.2 Tentatively Identified Compounds

Several Tentatively Identified Compounds (TICs) were reported in samples from Hi-Mill media. Any TIC reported as "unknown" was not considered in the risk assessment. Those TICs identified by name are listed in Table 8-1 and were evaluated qualitatively as an uncertainty in the assessment.

4.3.3 Comparison to Background

Some of the chemicals detected on-site occur naturally in soil, water and sediments and may not be related to site activities. Concentrations of inorganics were measured in soil samples from background locations and the results compared to measurements from site-related locations (Section 4.2 and Tables 4.1 through 4.3 of the RI Report). Zinc concentration in 81 of 95 site-related surface (0 to 1 foot deep) soil samples exceed background. Aluminum, chromium, copper and nickel exceed background concentrations in approximately two-thirds of the site-related surface soil samples. Silver concentrations exceed background in only four of the ninety-five surface soil samples. A similar pattern exists for shallow (1 to 3 feet deep) soils. Elevated concentrations of these metals are most common along the border between Target Pond and the manufacturing facility. These metals are not ruled out as chemicals of potential ecological concern.

Barium, beryllium, cadmium, calcium, iron, lead, magnesium, manganese, potassium and vanadium concentrations in soil samples from almost every site-related location are above background levels. Antimony, arsenic and sodium concentrations in some site-related samples also exceeded background concentrations. Cyanide, mercury and thallium concentrations in site-related samples never exceeded background levels. Although differences in soil types are likely to contribute to observed patterns of some elevated metals in site-related soil samples, only cyanide is eliminated as a chemical of potential ecological concern on the basis of the comparison between site and background levels.

The ranges of concentrations of inorganics in surface water and sediment are presented in Table 4-2. Background Pond is located southwest of Waterbury Lake. Aluminum, chromium and nickel are clearly elevated in Target Pond surface water compared to both background and Waterbury Lake sample results. Nickel occurs in Waterbury Lake at a level approximately ten times that measured in background pond surface water. All other inorganics occur at similar levels in the three surface water bodies.

Concentrations of calcium, iron, magnesium, manganese, potassium, and sodium are all above background in Target Pond surface water (Section 4.3.2.1 and Table 1 of Appendix R of the RI Report).

Aluminum, chromium, copper and zinc are all statistically elevated over background in Target Pond sediment. Nickel and silver are also elevated above background in Target Pond (Table 4-2). Chromium and copper are the only two inorganics that appear elevated in Waterbury Lake. Zinc levels are lowest in Waterbury Lake.

Elevated levels of metals in Target Pond correlate with the elevated levels in soils between Target Pond and the manufacturing facility.

TABLE 4-2 COMPARISION OF RANGE OF DETECTED CONCENTRATIONS IN SURFACE WATER AND SEDIMENT[a]

Chemical	Background Pond	Waterbury Lake	Target Pond
Surface Water (ug/L):			
Aluminum	ND[b]	ND	5360
Chromium (Total)	9.3	ND	9.3-28.5
Chromium (+6)	ND	ND	ND
Copper	19.5	ND	13-21.4
Nickel	13.8-17.8	122-143	143-302
Silver	9-12.5	ND	11.4
Zinc	11.8-12.4	9.4	6.7-16.2
Cyanide	ND	NR[c]	ND
Ammon. Nitrogen	50-160	ND	ND
Nitrate/Nitrite-N	70-180	ND	ND
Sediment (mg/kg):			
Aluminum	964-3610	1360-3770	11800-33900
Chromium (Total)	22.9-37.1	51.8	17.3-974
Chromium (+6)	NR	NR	NR
Copper	34.8	486	6.4-1860
Nickel	ND	28.1	7.3-41.9
Silver	ND	ND	2.2-3
Zinc	71.6-122	56.9-75.6	14-208

(a) Duplicate values are not averaged in this table. Source: Tables 4-9 and 4-10 in the RI Report.
(b) Not detected.
(c) Not reported.

4.3.4 Comparison to Blanks

Blank comparisons were made by Geraghty and Miller (1990; 1992) as described in Section 4.2. These comparisons were incorporated into the database by Life Systems. Any samples which were associated with contaminated blanks were appropriately "U" qualified in accordance with USEPA (1988c, 1991) guidance. Thus, common laboratory contaminants were retained as contaminants of potential ecological concern only if the concentration in one or more samples exceeded ten times the concentration in any associated blank. Other contaminants which were detected in both samples and blanks were retained only if the concentration in one or more samples was greater than five times the concentration in any associated blank.

4.3.5 Frequency of Detection

A number of chemicals were detected only once or twice out of all the on-site samples that were analyzed. These infrequently detected chemicals may be artifacts in the data due to sampling, analytical, or other problems, or they may be present on-site at very low levels that can be detected only infrequently. Some of these chemicals may have been used at or near the site and may be associated with site activities. In view of this, a conservative approach was adopted and these chemicals were retained as chemicals of potential ecological concern. Uncertainties due to including these chemicals in the quantitative risk assessment are addressed in Section 8.3.

4.3.6 List of Chemicals of Potential Ecological Concern

After excluding chemicals never detected, 46 chemicals remained as candidate chemicals of potential ecological concern. A summary of the analytical data on these chemicals is presented in Table 4-3, including frequency of detection and range of concentrations in surface soil, subsurface soil, groundwater, surface water and sediment. The ecological assessment focused on those contaminants on this list that were detected at least once in surface soil, surface water and sediment, the three environmental media where ecological resources are most likely to come in contact with the contaminants. These are listed in Table 4-4.

TABLE 4-3 SUMMARY OF DATA ON CANDIDATE CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN AT THE HI-MILL SITE

	Surface Soil						Subsurface Soil					
	Freq. of Detection		Range of Detects, mg/kg		Range of Detection Limits, mg/kg		Freq. of Detection		Range of Detects, mg/kg		Range of Detectio Limits, mg/kg	
Chemical Name	Hits	Total	Min.	Max.	Min.	Max.	Hits	Total	Min.	Max.	Min.	Max.
Inorganics												
Aluminum	79	79	2.1E+03	2.7E+04			106	106	1.7E+03	2.7E+04		
Antimony	1	8	1.7E+01	1.7E+01	1.3E+01	1.3E+02	1	6	9.7E+00	9.7E+00	1.2E+01	1.3E+01
Arsenic	8	8	3.2E+00	1.4E+01			6	6	2.3E+00	6.2E+00		
Barium	7	8	3.0E+01	1.3E+02	1.1E+02	1.1E+02	6	6	7.5E+00	1.4E+02		
Beryllium	6	8	3.4E-01	1.2E+00	2.9E-01	2.5E+00	5	6	2.7E-01	8.6E-01	1.2E-01	1.2E-01
Cadmium	7	8	8.0E-01	1.1E+01	6.3E-01	6.3E-01	5	6	5.9E-01	1.3E+00	5.0E-01	5.0E-01
Calcium	9	9	7.4E+02	1.1E+04			6	6	2.2E+04	1.0E+05		
Chromium	79	79	4.5E+00	4.4E+03			106	106	4.6E+00	1.6E+03		
Cobalt	6	8	4.8E+00	1.5E+01	4.5E+00	3.5E+01	6	6	3.2E+00	1.2E+01		
Copper	69	79	2.3E+00	5.0E+03	2.3E+00	3.6E+00	91	106	2.4E+00	4.4E+03	2.2E+00	2.6E+00
Iron	8	8	1.0E+04	4.3E+04			6	6	7.0E+03	2.9E+04		
Lead	8	8	1.5E+01	6.0E+01			6	6	6.2E+00	2.3E+01		
Magnesium	8	8	1.6E+03	8.2E+03			6	6	9.6E+03	2.7E+04		
Manganese	8	8	2.2E+02	7.6E+02			6	6	1.5E+02	4.3E+02		
Mercury	0	8			1.0E-01	8.6E-01	1	7	9.0E-02	9.0E-02	4.5E-02	1.3E-01
Nickel	77	78	5.0E+00	5.0E+01	2.8E+01	2.8E+01	106	106	4.9E+00	4.2E+01		
Potassium	7	8	4.7E+02	3.4E+03	2.0E+03	2.0E+03	6	6	2.9E+02	2.5E+03		
Selenium	0	8			2.6E-01	2.5E+00	0	6			1.2E-01	1.3E+00
Silver	0	79			1.0E+00	2.3E+01	3	106	1.2E+00	1.3E+01	9.4E-01	2.9E+00
Sodium	1	8	2.9E+02	2.9E+02	3.0E+02	2.7E+03	1	6	3.5E+02	3.5E+02	1.3E+02	2.8E+02
Vanadium	7	8	1.6E+01	5.2E+01	2.0E+01	2.0E+01	6	6	9.4E+00	3.6E+01		
Zinc	78	78	2.2E+01	8.4E+02			107	107	1.8E+01	2.4E+02		
Cyanide	0	8			6.4E-01	6.3E+00	0	6			3.0E-01	6.4E-01
Ammonia-N		NA[a]						NA				
Nitrate + Nitrite		NA						NA				
Volatiles												
Acetone	0	14			1.1E-02	1.4E-01	2	48	1.4E-02	2.4E-02	5.5E-03	1.5E-01
Bromodichloromethane	0	14			5.0E-03	6.0E-03	0	48			3.0E-03	3.1E-02
Butanone, 2-	0	14			1.1E-02	1.2E-02	0	48			5.5E-03	6.2E-02
Chlorobenzene	0	14			5.0E-03	6.0E-03	3	48	2.5E-03	1.4E-02	3.0E-03	3.1E-02
Chloroform	0	14			5.0E-03	6.0E-03	0	48			3.0E-03	3.1E-02
Dichloroethane,1,1-	0	14			5.0E-03	6.0E-03	0	48			3.0E-03	3.1E-02
Dichloroethene,1,2-(total)	0	14			5.0E-03	3.6E-02	12	48	2.0E-03	1.3E-01	3.0E-03	3.1E-02
Ethylbenzene	0	14			5.0E-03	6.0E-03	2	48	2.0E-03	2.5E-03	3.0E-03	3.1E-02
Methyl-2-pentanone,4-	0	14			1.1E-02	1.2E-02	1	48	5.0E-03	5.0E-03	5.5E-03	6.2E-02
Methylene chloride	0	14			6.0E-03	1.4E-02	1	48	5.1E-03	5.1E-03	3.0E-03	4.6E-02
Tetrachloroethane,1,1,2,2-	0	14			5.0E-03	6.0E-03	1	48	2.8E-03	2.8E-03	3.0E-03	3.1E-02

(a) NA = Chemical not analyzed for in this medium.

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continued-

Table 4-3 - continued

Chemical Name	Surface Soil: Freq. of Detection Hits	Surface Soil: Freq. of Detection Total	Surface Soil: Range of Detects, mg/kg Min.	Surface Soil: Range of Detects, mg/kg Max.	Surface Soil: Range of Detection Limits, mg/kg Min.	Surface Soil: Range of Detection Limits, mg/kg Max.	Subsurface Soil: Freq. of Detection Hits	Subsurface Soil: Freq. of Detection Total	Subsurface Soil: Range of Detects, mg/kg Min.	Subsurface Soil: Range of Detects, mg/kg Max.	Subsurface Soil: Range of Detection Limits, mg/kg Min.	Subsurface Soil: Range of Detection Limits, mg/kg Max.
Tetrachloroethene	0	14			5.0E-03	6.0E-03	2	48	6.8E-02	2.3E-01	3.0E-03	6.9E-03
Toluene	1	14	1.4E-01	1.4E-01	6.0E-03	9.0E-03	9	48	2.2E-03	3.7E-02	3.0E-03	3.1E-02
Trichloroethane,1,1,1-	1	14	2.0E-03	2.0E-03	5.0E-03	6.0E-03	4	48	1.0E-03	1.1E-02	3.0E-03	3.1E-02
Trichloroethane,1,1,2-	0	14			5.0E-03	6.0E-03	1	48	2.8E-03	2.8E-03	3.0E-03	3.1E-02
Trichloroethene	11	14	2.0E-03	4.3E-02	6.0E-03	6.0E-03	31	48	1.0E-03	6.1E+00	3.0E-03	6.3E-03
Vinyl acetate	0	14			1.1E-02	1.2E-02	0	48			5.5E-03	6.2E-02
Vinyl chloride	0	14			1.1E-02	1.2E-02	0	48			5.5E-03	6.2E-02
Xylenes(total)	0	14			5.0E-03	6.0E-03	3	49	2.0E-03	2.0E-03	2.0E-03	3.1E-02
Semivolatiles												
Bis(2-ethylhexyl)phthalate		NA					2	3	2.1E-01	2.9E-01	3.9E-01	3.9E-01
Di-n-butylphthalate		NA					1	3	1.2E-01	1.2E-01	3.9E-01	4.3E-01

continued-

Table 4-3 - continued

Chemical Name	Target Pond Surface Water: Freq. of Detection Hits	Total	Range of Detects, mg/L Min.	Max.	Range of Detection Limits, mg/L Min.	Max.	Target Pond Sediment: Freq. of Detection Hits	Total	Range of Detects, mg/kg Min.	Max.	Range of Detection Limits, mg/kg Min.	Max.
Inorganics												
Aluminum	1	9	5.4E+00	5.4E+00	4.3E-02	8.5E-02	25	25	1.4E+03	3.4E+04		
Antimony	0	3			2.6E-02	5.1E-02	0	9			6.3E+00	6.2E+01
Arsenic	0	3			1.5E-03	3.0E-03	9	9	1.2E+00	9.5E+00		
Barium	0	3			2.1E-02	4.2E-02	9	9	4.6E+01	2.7E+02		
Beryllium	0	3			5.0E-04	1.0E-03	4	9	6.7E-01	1.9E+00	7.7E-01	3.3E+00
Cadmium	0	3			1.0E-03	2.0E-03	4	9	1.5E+00	6.0E+00	3.1E+00	1.3E+01
Calcium	3	3	2.2E+01	4.4E+01			9	9	7.7E+03	3.5E+04		
Chromium	2	9	6.4E-03	1.4E-02	3.5E-03	2.9E-02	24	25	1.7E+01	2.4E+03	7.3E+00	7.3E+00
Cobalt	0	3			7.0E-03	1.4E-02	6	9	5.5E+00	1.2E+01	8.2E+00	1.3E+01
Copper	0	9			5.0E-03	1.3E-02	23	25	6.4E+00	1.7E+04	2.8E+00	1.0E+01
Iron	3	3	8.0E-02	6.3E-01			9	9	8.4E+03	2.2E+04		
Lead	2	3	3.1E-03	4.3E-03	2.0E-03	2.0E-03	9	9	1.1E+01	1.4E+02		
Magnesium	3	3	5.3E+00	1.2E+01			9	9	2.5E+03	2.5E+04		
Manganese	3	3	7.1E-02	3.8E-01			9	9	5.3E+01	2.3E+02		
Mercury	0	3			1.0E-04	2.0E-04	1	9	7.3E-01	7.3E-01	5.3E-02	1.6E+00
Nickel	5	9	1.4E-01	3.0E-01	5.5E-03	1.2E-01	24	25	7.3E+00	4.2E+01	2.2E+01	2.2E+01
Potassium	3	3	2.7E+00	3.7E+00			9	9	1.2E+03	2.5E+03		
Selenium	0	3			5.0E-04	1.0E-03	1	9	6.5E-01	6.5E-01	1.3E-01	6.6E+01
Silver	3	9	6.8E-03	1.1E-02	4.5E-03	9.0E-03	2	25	4.8E+00	9.6E+00	1.1E+00	1.8E+01
Sodium	3	3	8.7E+00	2.6E+01			4	9	5.0E+02	1.5E+03	9.4E+02	4.0E+03
Vanadium	0	3			4.0E-03	8.0E-03	8	9	1.5E+01	4.4E+01	1.3E+01	1.3E+01
Zinc	1	9	1.2E-02	1.2E-02	3.0E-03	1.3E-02	25	25	4.1E+01	1.2E+03		
Cyanide	0	4			1.0E-02	1.0E-02	0	3			3.1E-01	9.6E-01
Ammonia-N		NA						NA				
Nitrate + Nitrite	0	2			2.5E-02	5.0E-02		NA				

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Table 4-3 - continued

	Groundwater					
	Freq. of Detection		Range of Detects, mg/L		Range of Detection Limits, mg/L	
Chemical Name	Hits	Total	Min.	Max.	Min.	Max.
Inorganics						
Aluminum	14	68	5.9E-02	2.3E+02	2.8E-02	1.1E-01
Antimony	1	15	4.4E-02	4.4E-02	2.2E-02	5.6E-02
Arsenic	3	15	4.2E-03	1.0E-02	5.0E-04	3.0E-03
Barium	10	15	2.2E-02	8.7E-02	2.3E-02	4.2E-02
Beryllium	1	15	1.0E-03	1.0E-03	5.0E-04	2.0E-03
Cadmium	0	15			1.0E-03	4.0E-03
Calcium	15	15	5.9E+01	4.7E+02		
Chromium	9	68	5.8E-03	5.5E-01	3.1E-03	3.0E-02
Cobalt	3	15	7.3E-03	2.3E-02	2.0E-03	1.4E-02
Copper	11	68	5.2E-03	7.5E-01	2.4E-03	3.4E-02
Iron	10	15	4.8E-02	1.3E+01	1.0E-02	3.9E-02
Lead	2	15	2.5E-03	1.1E-02	7.0E-04	3.2E-03
Magnesium	15	15	1.8E+01	5.3E+02		
Manganese	14	15	4.9E-02	1.9E+00	1.0E-03	1.0E-03
Mercury	2	15	2.0E-04	3.6E-04	1.0E-04	2.0E-04
Nickel	25	68	1.0E-02	6.7E-01	5.5E-03	1.9E-02
Potassium	13	15	6.6E-01	1.2E+01	9.6E-01	9.6E-01
Silver	1	68	1.5E-02	1.5E-02	3.3E-03	9.0E-02
Sodium	15	15	3.5E+00	5.8E+02		
Vanadium	4	15	7.9E-03	2.2E-02	2.5E-03	8.0E-03
Zinc	22	68	4.5E-03	2.2E+00	2.5E-03	1.5E-02
Cyanide	1	7	3.7E-02	3.7E-02	5.0E-03	1.0E-02
Ammonia-N	17	24	5.0E-02	2.2E+00	5.0E-02	5.0E-02
Nitrate + Nitrite	13	24	5.0E-02	1.6E+01	5.0E-02	5.0E-02
Volatiles						
Acetone	7	56	2.0E-03	5.8E-02	5.0E-03	5.0E-01
Bromodichloromethane	1	56	1.0E-03	1.0E-03	2.5E-03	5.0E-01
Butanone, 2-	1	56	2.8E-02	2.8E-02	5.0E-03	5.0E-01
Chlorobenzene	0	56			2.5E-03	5.0E-01
Chloroform	1	56	2.0E-03	2.0E-03	2.5E-03	5.0E-01
Dichloroethane, 1,1-	1	56	2.0E-03	2.0E-03	2.5E-03	5.0E-01
Dichloroethene, 1,2- (total)	12	56	2.0E-03	1.4E+00	2.5E-03	1.0E-02
Ethylbenzene	0	56			2.5E-03	5.0E-01
Methyl-2-pentanone, 4-	1	56	1.0E-03	1.0E-03	5.0E-03	5.0E-01
Methylene chloride	0	56			5.0E-03	5.0E-01
Tetrachloroethane, 1,1,2,2-	0	56			2.5E-03	5.0E-01
Tetrachloroethene	0	56			2.5E-03	5.0E-01
Toluene	2	56	2.0E-03	3.0E-03	2.5E-03	5.0E-01
Trichloroethane, 1,1,1-	2	56	1.0E-03	1.0E-01	2.5E-03	5.0E-02
Trichloroethane, 1,1,2-	0	56			2.5E-03	5.0E-01

continued-

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Table 4-3 - continued

Chemical Name	Groundwater: Freq. of Detection: Hits	Total	Range of Detects, mg/L: Min.	Max.	Range of Detection Limits, mg/L: Min.	Max.
Trichloroethene	12	56	2.0E-03	6.7E+00	2.5E-03	1.0E-02
Vinyl acetate	1	47	1.0E-02	1.0E-02	5.0E-03	5.0E-01
Vinyl chloride	3	56	3.5E-03	6.8E-02	5.0E-03	5.0E-01
Xylenes(total)	1	56	3.0E-03	3.0E-03	2.5E-03	5.0E-01
<u>Semivolatiles</u>						
Bis(2-ethylhexyl)phthalate	0	3			5.0E-03	1.0E-02
Di-n-butylphthalate	1	3	6.5E-03	6.5E-03	1.0E-02	1.0E-02

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TABLE 4-4 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN AT THE HI-MILL SITE

Inorganics	Organics
Aluminum	Toluene
Antimony	Trichloroethane, 1,1,1-
Arsenic	Trichloroethene
Barium	
Beryllium	
Cadmium	
Calcium	
Chromium	
Cobalt	
Copper	
Iron	
Lead	
Magnesium	
Manganese	
Mercury	
Nickel	
Potassium	
Selenium	
Silver	
Sodium	
Vanadium	
Zinc	

5.0 EXPOSURE ASSESSMENT

5.1 Approach

An ecological exposure assessment involves estimating the magnitude, frequency and duration of exposures of ecosystem components to contaminants of ecological concern and analyzing uncertainties associated with exposure estimates (USEPA 1991a, 1989b). Exposure is the contact of a chemical agent with the outer boundary (skin, lung surface, etc.) of an organism.

An exposure assessment involves the following steps (USEPA 1991a):

- Source characterization
- Fate and transport analysis
- Identification of exposure routes
- Estimation of exposure point concentrations
- Characterization of activity patterns and species abundances at exposure points
- Estimation of chemical intakes

Source characterization involves estimating the magnitude and patterns of chemical releases to the environment. Fate and transport analysis involves developing estimates or measuring the spatial and temporal patterns of movement of chemicals through environmental media (air, soil and water), as well as biotic and abiotic transformations. Identification of exposure routes refers to determining the relative importance of ingestion, dermal/surface contact and inhalation/respiration as principal routes of exposure. Estimation of exposure point concentrations involves identification of exposure points and estimation of concentrations in environmental media at those locations. Characterization of activity patterns and species abundance is necessary for developing species- and endpoint-specific exposure estimates.

The first three steps have been completed and are discussed in the RI (Geraghty and Miller 1992) and the human health evaluation (Life Systems 1992) reports for the Hi-Mill site. Results are summarized as a conceptual site model (Figure 5-1).

A large number of exposure pathways involving ecological resources are possible at the Hi-Mill site. Not all of these pathways are likely to lead to exposures that could result in significant adverse effects.

Contact with surface soil, surface water and sediment is highly likely for resident animals and plants growing on the site. Therefore, exposure to surface soil, surface water and sediment are considered to be the exposure media of greatest concern at this site.

Indirect exposure to contaminated media may occur as a result of bioaccumulation and food chain transfer. Food chain transfer may occur in aquatic and terrestrial ecosystems and is associated with both plant- and decomposer-based food chains. Bioaccumulation in aquatic organisms includes direct uptake from water and uptake through ingestion of contaminated food organisms. Direct uptake is referred to as bioconcentration. Bioconcentration factors are used to express uptake by aquatic organisms. Representative values for contaminants of potential ecological concern and aquatic species observed or potentially present in surface waters at the Hi-Mill site are

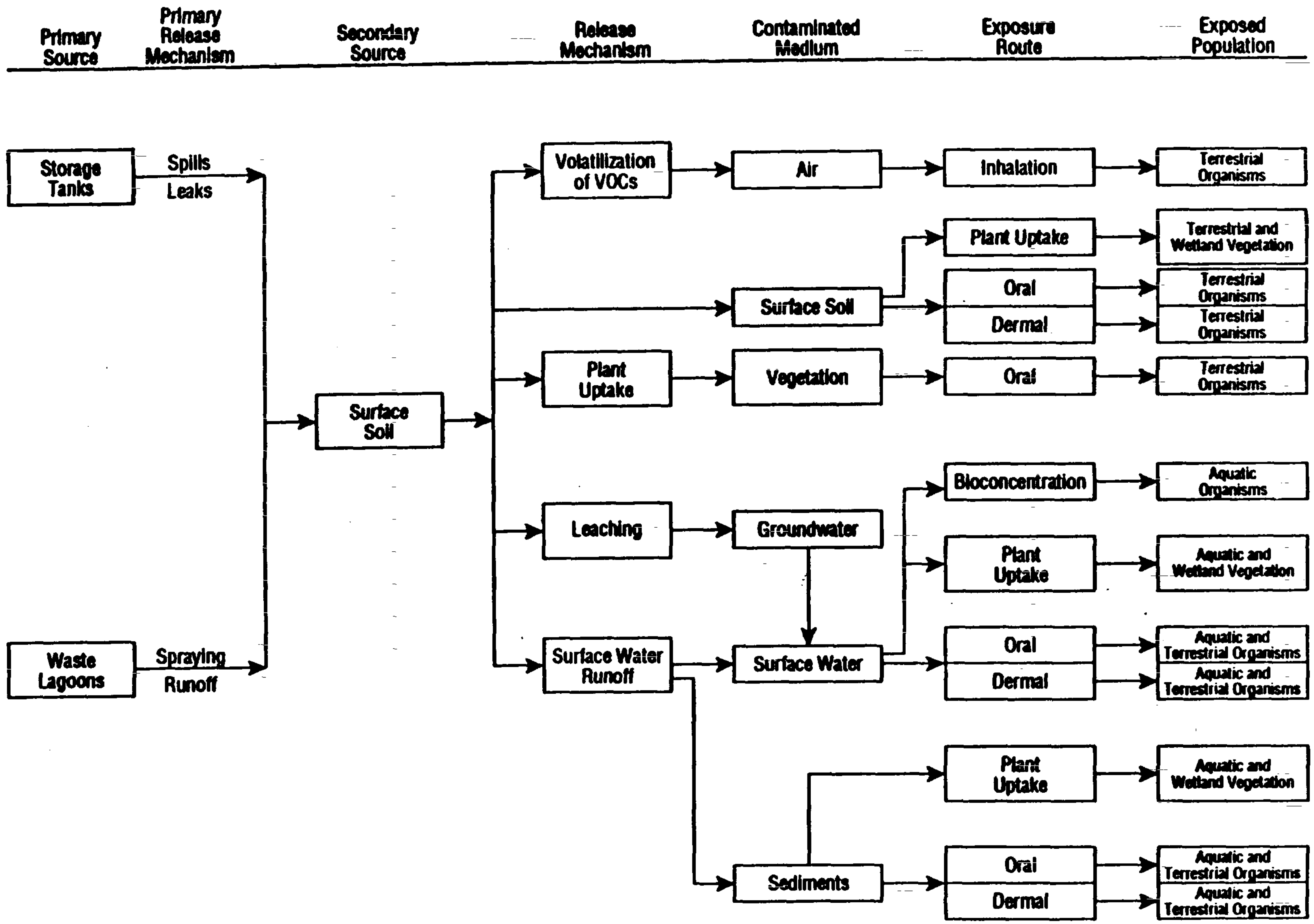

FIGURE 5-1 GENERALIZED CONCEPTUAL SITE MODEL

Life Systems, Inc.

provided in Table 5-1. Copper, zinc, arsenic and cadmium have the greatest potential for bioconcentration at this site. Contribution to bioaccumulation by ingestion of contaminated organisms is species- and food chain-specific and cannot be estimated with information available for this site.

Uptake by terrestrial plants exposed to contaminants in soil and dust deposited on leaves may also contribute to food chain transfer in terrestrial communities. Root concentration factors for metals detected in surface soils vary widely (Table 5-2). Several of the elements essential for plant growth have the highest uptake factors. Uptake is dependent on site characteristics and exposed species (Bodek et al. 1988). Therefore, it is not possible to evaluate plant uptake quantitatively at this site.

Earthworms and other soil macroinvertebrates take up metals from soil selectively (Kabata-Pendias and Pendias 1989). Cadmium and zinc are accumulated by a factor of between 20 and 30, while lead and nickel are accumulated by a factor of two to three (Table 5-3). Copper, mercury and manganese are not accumulated by earthworms.

Inhalation of VOCs released to air from soil and groundwater is not likely to represent a major exposure pathway for any terrestrial population relative to other pathways at this site. Areas of VOC contamination are highly disturbed and not likely to represent suitable habitat for important ecological resources. Groundwater and subsurface soil are not expected to represent important exposure media at this site, since direct contact with these media is highly unlikely.

5.2 Estimation of Exposure Concentrations

Exposure points at the Hi-Mill site have been defined by matching the location of the site samples (Section 4.0) with the ecological features of the site (Section 3.0). Exposure points for this ecological assessment are defined as follows:

- On-site surface soil (0-1 feet deep)
- Target Pond (surface water and sediment)
- Waterbury Lake (surface water and sediment)

Summary statistics for exposure point concentrations at these locations are provided in Appendix 1. Sample locations used to prepare tables in Appendix 1 are listed in Table 5-4. Summary statistics in Appendix 1 are based on soil concentrations in surface soil samples only.

5.3 Activity Patterns and Species Abundances

Aquatic organisms, vascular plants, terminal predators and burrowing animals (e.g., earthworms, crayfish, moles, woodchucks) are likely to receive the highest exposures to contaminants of potential ecological concern. Resident wildlife, which spend less than a lifetime on site, are likely to receive low to moderate exposures to site contaminants. Small mammals whose home range is contained entirely on site are likely to receive a proportionately greater exposure than larger mammals and birds that may spend a fraction of their time on site throughout the year or on a seasonal basis. Migratory waterfowl are likely to receive the lowest exposure to contaminated media on site.

TABLE 5-1 BIOCONCENTRATION FACTORS FOR CONTAMINANTS OF POTENTIAL ECOLOGICAL CONCERN IN SURFACE WATER AND SEDIMENT

Chemical	BCF	Species	Source
Inorganics			
Aluminum	NA[a]		
Antimony	ND[b]		(c)
Arsenic	350	Geometric mean[d]	(c)
Barium	NA		
Beryllium	ND		(c)
Cadmium	326	Geometric mean	(c)
Calcium	NA		
Chromium III	127	Geometric mean	(c)
Chromium V	155	Geometric mean	(c)
Cobalt	NA		
Copper	1,183	Geometric mean	(c)
Iron	NA		
Lead	179	Geometric mean	(c)
Magnesium	NA		
Manganese	NA		
Mercury	NA		(c)
Nickel	50	Geometric mean	(c)
Potassium	NA		
Selenium	ND		(c)
Silver	ND		(c)
Sodium	ND		(c)
Thallium	15	Geometric mean	(c)
Vanadium	NA		
Zinc	578	Geometric mean	(c)
Cyanide	NA		

(a) Not available.
(b) No data.
(c) USEPA 1989d.
(d) Species used to calculate mean not identified in reference.

TABLE 5-2 SOIL-TO-PLANT CONCENTRATION FACTORS FOR METALS[a]

Metal	Vegetative Portion	Nonvegetative (Reproductive) Portion
Aluminum	0.004	0.00065
Antimony	0.2	0.03
Arsenic	0.04	0.006
Barium	0.15	0.015
Beryllium	0.01	0.0015
Cadmium	0.55	0.15
Calcium	3.5	0.35
Chromium	0.0075	0.0045
Cobalt	0.02	0.007
Copper	0.4	0.25
Iron	0.004	0.001
Lead	0.045	0.009
Magnesium	1	0.55
Manganese	0.25	0.05
Mercury	0.9	0.2
Nickel	0.06	0.06
Potassium	1	0.55
Selenium	0.025	0.025
Silver	0.4	0.1
Sodium	0.075	0.055
Thallium	0.004	0.0004
Vanadium	0.0055	0.003
Zinc	15	0.9

(a) Source: Bodek et al. 1988. Data for food crops and feed plants.

TABLE 5-3 ACCUMULATION OF METALS IN EARTHWORMS EXPOSED TO CONTAMINATED SOIL[a]

	Worm/Soil Conc. Ratio		Metal Conc., ppm	
Metal	Level	Value	Soil	Worm
Cd	Min	1	4	4
	Max	27.6[b]	4.1	10.3
Cu	Min	0.03	335	11
	Max	0.69	26	18
Hg	Min	0.33	3.8	1.29[c]
	Max	0.40	0.1	0.04[c]
Mn	Min	0.06	1,330	82
	Max	0.16	164	27
Ni	Min	1.19	26	31
	Max	2.66	12	32
Pb	Min	0.01	629	9
	Max	2.73	1,314	3,592
Zn	Min	0.68	992	676
	Max	22.5	40	900

(a) Source: Kabata-Pendias and Pendias 1989. Metal concentrations expressed on a dry weight basis. Data reported for Lumbrius nibellus or L. terrestris, except as noted.
(b) Data for other invertebrates.
(c) Fresh weight basis.

TABLE 5-4 SUMMARY OF SAMPLES USED TO CALCULATE EXPOSURE POINT CONCENTRATIONS

Exposure Point	Medium	Samples Used in EPC Calculation
On-site, Behind Hi-Mill Building	Surface Soil	A1-0, A2-0, A3-0, A4-0, B1-0, B2-0, B3-0, B4-0, B5-0, C1-0, C2-0, C3-0, C4-0, C5-0, D2-0, D3-0, D4-0, D5-0, D6-0, E2-0, E3-0, E4-0, E5-0, E6-0, E7-0, F3-0, F4-0, F5-0, F6-0, F7-0, F8-0, G3-0, G3/H4-0, G4-0, G5-0, G6-0, G7-0, G8-0, H3-0, H3/I3-0, H4-0, H4/I5-0, H5-0, H6-0, H7-0, H8-0, I5-0, I6-0, I8-0, J5-0, J6-0, J7-0, K3-0, K4-0, K5-0, K6-0, L3-0, L4-0, L5-0, M3-0, M4-0
Target Pond	Surface Water	TP1, TP2, TP4, TP7, TP9, TP10, TP11
	Sediment	TP1-0, TP2-0, TP3-0, TP4, TP4-0, TP4-1, TP5-0, TP6-0, TP6-1, TP7-0, TP7-1, TP8, TP8-0, TP8-1, TP9-0, TP10-0, TP11-0, TP11-1, TP12-0, TP13, TP14
Waterbury Lake	Surface Water	WL-1, WL-2
	Sediment	WL-1, WL-2

5.4 Estimation of Chemical Intakes

Characterization of activity patterns and species abundance at exposure points beyond that provided in Section 3.0 is not possible for all the potential ecological receptors (Table 5-5) at this site. Calculation of doses and intakes for specific populations are also beyond the scope of this assessment. However, the relative magnitude of the potential exposures can be subjectively ranked from high to very low based on potential exposure frequency, duration and degree of contact with contaminated media during exposure (Table 5-5).

Bioavailability of contaminants in soil, surface water (i.e., measurements of total metals) and sediment is a major uncertainty in interpreting bulk concentration estimates.

TABLE 5-5 EXPOSURE SCENARIOS FOR ECOLOGICAL POPULATIONS

Exposure Point	Exposure Population	Exposure Activity	Relative Potential Magnitude of Exposure
Target Pond and Waterbury Lake	Benthic invertebrates	Direct uptake, feeding	High
	Fish	Direct uptake, feeding	High
	Phytoplankton	Direct update	High
	Zooplankton	Direct uptake, feeding	High
	Resident shorebirds	Ingestion of water, soil and sediment; feeding	Low to moderate
	Migratory waterfowl	Ingestion of water soil and sediment; feeding	Very low
	Terrestrial wildlife (Including avian predators)	Ingestion of water, soil and sediment; feeding	Low to moderate
	Aquatic macrophytes	Direct uptake	High
	Aquatic organisms exposed to runoff from watershed	Direct uptake, feeding	Low to moderate
Terrestrial Locations	Terrestrial plants	Growth in contaminated soil; uptake	Very Low to High
	Terrestrial invertebrates and wildlife (Including burrowing animals, soil invertebrates avian predators, e.g., hawks)	Ingestion of contaminated water and soil; direct contact with contaminated soil; consumption of contaminated plants and animals	
Wetlands	Wetland vegetation exposed to runoff and contaminated soil	Direct uptake	Moderate to High

6.0 CHARACTERIZATION FO IMPACTS AND RISKS

Risk and impact characterization are accomplished for this site by comparing exposure levels at the site to levels known to be toxic to aquatic resources and identifying potential areas of vegetation stress from the site survey that may be related to contamination at the site. Results of sediment toxicity testing is also used to characterize impacts to aquatic organisms. Summaries of the ecotoxicity of metals that are elevated in site sediment, surface water and surface soil are provided in Appendix 2.

6.1 Aquatic Resources

6.1.1 Surface Water

A comparison of maximum surface water concentrations and numerical criteria for protection of freshwater aquatic life is provided in Table 1 of Appendix R to the RI Report. Measured concentrations of the following inorganics exceed USEPA and/or MDNR Rule 57(2) numerical criteria:

- Copper in Target Pond
- Nickel in Target Pond and Waterbury Lake
- Silver in Target Pond and Waterbury Lake

The maximum silver concentration in surface water in the background pond is higher than the concentrations in either Target Pond or Waterbury Lake, suggesting those levels may not be site-related.

Aluminum is significantly elevated in Target Pond. Both draft USEPA numerical criteria for protection of aquatic life (Appendix 2) are exceeded at the maximum measured concentration in Target Pond.

Several other inorganics were not detected in surface water, but the detection limits achieved in the analyses exceeded the numerical criteria for protection of freshwater aquatic life. These include:

- Cadmium
- Chromium VI
- Cyanide
- Mercury

These elevated detection limits introduce an uncertainty in characterizing potential adverse effects to aquatic biota in Target Pond and Waterbury Lake.

The presence of concentrations of aluminum, copper, nickel and silver in Target Pond and Waterbury Lake that exceed numerical criteria for protection of aquatic life suggest that aquatic biota may be at risk in these surface water bodies.

The presence of a well developed phytoplankton and zooplankton communities suggests that organisms may have adapted to elevated concentrations of metals in Target Pond and Waterbury Lake surface water.

6.1.2 Sediment

Sediment toxicity tests were conducted using the amphipod Hyalella azteca and sediment from Target Pond and Waterbury Lake (Appendix R to the RI Report). The median percentage survival of the test organism using Target Pond sediment ranged from 50 percent to 80 percent. The median survival in tests of sediment samples from Waterbury Lake was 85 percent. A statistically significant reduction in percentage survival occurred in organisms exposed to sediment from location TP08 from Target Pond. A statistically significant correlation was identified between sediment toxicity and chromium concentration. The correlation was stronger between toxicity and pH and percent solid than between toxicity and chromium.

A series of benchmark sediment concentrations have been developed for evaluating biological effects of sediment contamination by the National Oceanic and Trends Program (Long and Morgan 1991). Two of these benchmark concentrations, the Effects Range-Low (ER-L) and Effects Range-Median (ER-M), represent the lower ten percentile and 50th percentile concentrations of the range over which effecdts have been observed at contaminated sites. These benchmark concentrations were compared to measured concentrations in sediment at this site (Table 6-1). These comparisons suggest that there is a potential for adverse biological effects in aquatic organisms exposed to sediment contaminated with cadmium, chromium, copper, lead, mercury, nickel, silver and zinc in Target Pond and copper in Waterbury Lake. The finding of a correlation between sediment toxicity and chromium in Target Pond sediment is consistent with the presence of chromium concentrations that are greater than the biological effects sediment benchmark concentration.

The presence of a macrobenthic invertebrate community in Target Pond suggests that considerable adaptation to elevated concentrations of metals has occurred among these organisms. High levels of organic material in Target Pond may reduce bioavailability of metals to exposed organisms.

6.2 Wetlands

Wetland vegetation is well developed along the margins of Target Pond and Waterbury Lake (Appendix R to the RI Report). Examination of historical growth patterns among dead swamp white oaks (Quercus bicolor) could not be attributed solely to chemical contamination along the western shore of Target Pond. High water has been suggested as the cause of the death of these trees.

6.3 Terrestrial Resources

Vegetation stress was noted during the site survey in a number of areas in the vicinity of the Hi-Mill site (Appendix R of the RI Report). These include:

- The shore of the north arm of Waterbury Lake
- The area between the Hi-Mill facility and Target Pond
- A small area along the fenceline of the Hi-Mill facility and Target Pond
- A small area in the northeastern corner of the site

TABLE 6-1 COMPARISON OF MEASURED SEDIMENT CONCENTRATIONS TO BIOLOGICAL EFFECTS BENCHMARK CONCENTRATIONS[a]

Chemical	Target Pond Max	Target Pond Ave	Waterbury Lake Max	Waterbury Lake Ave	Background Pond Max	Background Pond Ave	Sediment Benchmark Value ER-L	Sediment Benchmark Value ER-M
Aluminum	34,000	20,000	6,770	4,100	3,610	2,294	NA[b]	NA
Antimony	ND[c]	ND	-[d]	-	-	-	2	25
Arsenic	6.7	4.1	-	-	-	-	33	85
Barium	270	180	-	-	-	-	NA	NA
Beryllium	1.9	0.92	-	-	-	-	NA	NA
Cadmium	6	2.9	-	-	-	-	5	9
Calcium	35,000	15,000	-	-	-	-	NA	NA
Chromium	2,400	360	52	28	37.1	21.3	80	145
Cobalt	12	7.2	-	-	-	-	NA	NA
Copper	17,000	2,000	490	250	34.8	21.3	70	390
Iron	22,000	18,000	-	-	-	-	NA	NA
Lead	140	62	-	-	-	-	35	110
Magnesium	25000	7,600	-	-	-	-	NA	NA
Manganese	230	160	-	-	-	-	NA	NA
Mercury	0.73	0.31	-	-	-	-	0.15	1.3
Nickel	42	24	28.1	20	ND	ND	30	50
Potassium	2500	1,900	-	-	-	-	NA	NA
Selenium	0.65	0.65	-	-	-	-	NA	NA
Silver	4.8	1.8	ND	ND	ND	ND	1	2.2
Sodium	1500	870	-	-	-	-	NA	NA
Vanadium	44	36	-	-	-	-	NA	NA
Zinc	1,200	220	76	66	122	53.9	120	270

(a) Source: Target Pond-Human Health Evaluation Appendix A1.
All others, Table 4-1 in the RI Report.
All concentrations in mg/kg.
Highlighted entries exceed at least one benchmark.
(b) Not available.
(c) Not detected.
(d) Not analyzed.

None of the stressed vegetation was related to chemical contamination (Geraghty & Miller 1992). No other adverse effects of surface soil contamination were observed among terrestrial resources during the site survey.

7.0 ASSESSMENT UNCERTAINTIES

There are several major uncertainties in this assessment.

1. The sediment samples that were collected do not clearly establish a relationship between metal contamination in Target Pond and Waterbury Lake and historical and current patterns of releases of metals from Hi-Mill site sources.

2. The biological samples that were collected from Waterbury Lake do not clearly characterize macrobenthic communities.

3. Fish populations were not sampled in Target Pond, Waterbury Lake or the background reference pond. This may have required an intensive effort. As a result, conclusions cannot be drawn regarding whether conditions are suitable for fish in Target Pond and Waterbury Lake, or if they are, whether or not these communities are impacted by metals contamination. Food organisms (plankton and benthich invertebrates) are present in Target Pond, which is one reason to believe Target Pond should otherwise support at least a limited fish community.

4. Detection limits were too high to adequately characterize the potential risks from very low exposure levels for several metals which are very toxic to freshwater aquatic life at very low concentrations.

The uncertainties these situations impose on the data limit the extent of conclusions in this assessment.

8.0 CONCLUSIONS

An environmental evaluation was conducted for the Hi-Mill Superfund Site. The following conclusions are based on personal observations, survey results, and documents available through August, 1992.

8.1 Target Pond and Waterbury Lake

Sediments in Target Pond are clearly contaminated with elevated levels of toxic metals that exceed sediment toxicity benchmark concentrations. Limited toxicity has been demonstrated in sediment samples from Target Pond. Numerical criteria for protection of aquatic life are also exceeded by metal (aluminum, copper, nickel, and silver) concentrations in Target Pond surface water. Fairly significant plankton and benthic macroinvertebrate communities are present in Target Pond in spite of elevated sediment and surface water metal concentrations. The presence of naturally-occurring organic materials in the pond are likely to reduce significantly the bioavailability of the metals to aquatic organisms. Samples does not clearly establish a link between measured contaminant levels in Target Pond and historical or current releases of metals from the Hi-Mill facility. The absence of information on the presence of fish populations in Target Pond is a significant uncertainty in the assessment, however, Target Pond planktonic and benthic communities are likely to represent food supplies sufficient to support fish populations.

Nickel and silver levels in Waterbury Lake exceed numerical criteria for protection of aquatic life. Copper concentration in Waterbury Lake sediment exceeds a sediment toxicity benchmark. A particular concern is the absence of macrobenthic organisms in samples from Waterbury Lake, however, it cannot be concluded that there are no macrobenthic organisms present.

8.2 Wetlands

Wetland vegetation is abundant along the edge of Target Pond and Waterbury Lake. No site-related impacts were identified during the site survey. The death of swamp white oaks near the Hi-Mill facility does not appear related to chemical releases from the site.

8.3 Terrestrial Resources

No data are available that indicate that chemical contamination related to releases from the Hi-Mill site has resulted in adverse impacts to terrestrial animals or plants of ecological or social importance.

8.4 Endangered and Threatened Species

No data indicate that endangered and threatened species are present in the vicinity of the Hi-Mill site.

8.5 Assessment Uncertainties

The primary uncertainties in this assessment are related to undersampling in areas of ecological concern where ecological resources may be exposed to site releases. This factor limits conclusions to those of a qualitative nature, and does not allow a clear definition of the contribution of releases of metals from the the Hi-Mill site to Target Pond or the full extent of potential impacts to ecological resources in this area.

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APPENDIX 1

EXPOSURE POINT CONCENTRATIONS CALCULATIONS

The following worksheets provide detail on the calculations of exposure point concentrations. Each worksheet consists of chemical sample concentrations and a summary of statistics for that exposure point.

The following provides a page reference to each.

File Name	Exposure Point	Medium	Page
S_STAT	On-site	Surface Soil	A1-2
SW_STAT	Target Pond	Surface Water	A1-3
SD_STAT	Target Pond	Sediment	A1-4
WW_STAT	Waterbury Lake	Surface Water	A1-5
WD_STAT	Waterbury Lake	Sediment	A1-6

DATA STATISTICS

DATE: 09/18/92
FILENAME S_STAT

EXPOSURE POINT: ON-SITE
MEDIUM: SURFACE SOIL
UNITS: MG/KG
U MULTIPLIER: 0.5

	CHEMICAL	EPC HITS	EPC TOTAL	MAX HIT	MIN VALUE	ARITH MEAN	AM95
1	Aluminum	61	61	2.7E+04	2.2E+03	1.2E+04	1.3E+04
2	Antimony	1	4	1.7E+01	6.5E+00	2.4E+01	5.6E+01
3	Arsenic	4	4	1.4E+01	3.3E+00	7.4E+00	1.3E+01
4	Barium	3	4	1.3E+02	5.3E+01	7.4E+01	1.2E+02
5	Beryllium	3	4	1.2E+00	3.4E-01	8.1E-01	1.4E+00
6	Cadmium	4	4	1.1E+01	1.0E+00	3.6E+00	9.1E+00
7	Calcium	4	4	1.1E+04	1.9E+03	5.0E+03	9.6E+03
8	Chromium	61	61	4.4E+03	7.4E+00	1.1E+02	2.3E+02
9	Cobalt	2	4	1.5E+01	2.3E+00	1.0E+01	1.9E+01
10	Copper	52	61	5.0E+03	1.2E+00	3.3E+02	5.1E+02
11	Iron	4	4	4.3E+04	1.3E+04	2.2E+04	3.9E+04
12	Lead	4	4	6.0E+01	1.5E+01	2.9E+01	5.3E+01
13	Magnesium	4	4	8.2E+03	2.1E+03	3.8E+03	7.3E+03
14	Manganese	4	4	7.6E+02	4.2E+02	5.6E+02	7.5E+02
15	Mercury	0	4	ERR	6.0E-02	1.6E-01	3.7E-01
16	Nickel	59	60	5.0E+01	5.0E+00	1.5E+01	1.7E+01
17	Potassium	3	4	3.4E+03	7.8E+02	1.5E+03	3.0E+03
18	Selenium	0	4	ERR	1.3E-01	4.3E-01	1.1E+00
19	Silver	0	61	ERR	1.0E+00	1.4E+00	1.7E+00
20	Sodium	1	4	2.9E+02	1.8E+02	5.0E+02	1.2E+03
21	Vanadium	3	4	5.2E+01	1.0E+01	2.7E+01	4.8E+01
22	Zinc	61	61	8.4E+02	2.2E+01	1.1E+02	1.4E+02
23	Cyanide	0	4	ERR	3.2E-01	1.1E+00	2.7E+00
24	Ammonia-N	0	0	ERR	ERR	ERR	ERR
25	Nitrate + Nitrite	0	0	ERR	ERR	ERR	ERR
26	Acetone	0	0	ERR	ERR	ERR	ERR
27	Bromodichloromethan	0	0	ERR	ERR	ERR	ERR
28	Butanone, 2-	0	0	ERR	ERR	ERR	ERR
29	Chlorobenzene	0	0	ERR	ERR	ERR	ERR
30	Chloroform	0	0	ERR	ERR	ERR	ERR
31	Dichloroethane, 1,1-	0	0	ERR	ERR	ERR	ERR
32	Dichloroethene, 1,2- (t	0	0	ERR	ERR	ERR	ERR
33	Ethylbenzene	0	0	ERR	ERR	ERR	ERR
34	Methyl-2-pentanone, 4-	0	0	ERR	ERR	ERR	ERR
35	Methylene chloride	0	0	ERR	ERR	ERR	ERR
36	Tetrachloroethane, 1,1,	0	0	ERR	ERR	ERR	ERR
37	Tetrachloroethene	0	0	ERR	ERR	ERR	ERR
38	Toluene	0	0	ERR	ERR	ERR	ERR
39	Trichloroethane, 1,1,1-	0	0	ERR	ERR	ERR	ERR
40	Trichloroethane, 1,1,2-	0	0	ERR	ERR	ERR	ERR
41	Trichloroethene	0	0	ERR	ERR	ERR	ERR
42	Vinyl acetate	0	0	ERR	ERR	ERR	ERR
43	Vinyl chloride	0	0	ERR	ERR	ERR	ERR
44	Xylenes (total)	0	0	ERR	ERR	ERR	ERR
45	Bis(2-ethylhexyl)phthal	0	0	ERR	ERR	ERR	ERR
46	Di-n-butylphthalate	0	0	ERR	ERR	ERR	ERR

DATA STATISTICS

DATE: 09/18/92
FILENAM SW_STAT

EXPOSURE POINT: TARGET POND
MEDIUM: SURFACE WATER
UNITS: MG/L
U MULTIPLIER: 0.5

	CHEMICAL	EPC HITS	EPC TOTAL	MAX HIT	MIN VALUE	ARITH MEAN	AM95
1	Aluminum	1	7	5.4E+00	4.3E-02	8.0E-01	2.3E+00
2	Antimony	0	3	ERR	2.6E-02	2.6E-02	2.6E-02
3	Arsenic	0	3	ERR	1.5E-03	1.5E-03	1.5E-03
4	Barium	0	3	ERR	2.1E-02	2.1E-02	2.1E-02
5	Beryllium	0	3	ERR	5.0E-04	5.0E-04	5.0E-04
6	Cadmium	0	3	ERR	1.0E-03	1.0E-03	1.0E-03
7	Calcium	3	3	4.4E+01	2.2E+01	3.2E+01	5.1E+01
8	Chromium	2	7	1.4E-02	3.5E-03	6.9E-03	1.1E-02
9	Cobalt	0	3	ERR	7.0E-03	7.0E-03	7.0E-03
10	Copper	0	7	ERR	5.0E-03	5.6E-03	6.5E-03
11	Iron	3	3	6.3E-01	8.0E-02	3.7E-01	8.3E-01
12	Lead	2	3	4.3E-03	1.0E-03	2.8E-03	5.6E-03
13	Magnesium	3	3	1.2E+01	5.3E+00	8.6E+00	1.4E+01
14	Manganese	3	3	3.8E-01	7.1E-02	1.7E-01	4.7E-01
15	Mercury	0	3	ERR	1.0E-04	1.0E-04	1.0E-04
16	Nickel	4	7	3.0E-01	5.5E-03	1.4E-01	2.5E-01
17	Potassium	3	3	3.7E+00	2.7E+00	3.1E+00	4.0E+00
18	Selenium	0	3	ERR	5.0E-04	5.0E-04	5.0E-04
19	Silver	2	7	1.1E-02	4.5E-03	5.8E-03	7.7E-03
20	Sodium	3	3	2.6E+01	8.7E+00	1.9E+01	3.4E+01
21	Vanadium	0	3	ERR	4.0E-03	4.0E-03	4.0E-03
22	Zinc	1	7	1.2E-02	3.0E-03	4.8E-03	7.4E-03
23	Cyanide	0	3	ERR	5.0E-03	5.0E-03	5.0E-03
24	Ammonia-N	0	0	ERR	ERR	ERR	ERR
25	Nitrate+Nitrite	0	1	ERR	2.5E-02	2.5E-02	ERR
26	Acetone	0	0	ERR	ERR	ERR	ERR
27	Bromodichloromethan	0	0	ERR	ERR	ERR	ERR
28	Butanone, 2-	0	0	ERR	ERR	ERR	ERR
29	Chlorobenzene	0	0	ERR	ERR	ERR	ERR
30	Chloroform	0	0	ERR	ERR	ERR	ERR
31	Dichloroethane, 1,1-	0	0	ERR	ERR	ERR	ERR
32	Dichloroethene, 1,2- (t	0	0	ERR	ERR	ERR	ERR
33	Ethylbenzene	0	0	ERR	ERR	ERR	ERR
34	Methyl-2-pentanone, 4-	0	0	ERR	ERR	ERR	ERR
35	Methylene chloride	0	0	ERR	ERR	ERR	ERR
36	Tetrachloroethane, 1,1,	0	0	ERR	ERR	ERR	ERR
37	Tetrachloroethene	0	0	ERR	ERR	ERR	ERR
38	Toluene	0	0	ERR	ERR	ERR	ERR
39	Trichloroethane, 1,1,1-	0	0	ERR	ERR	ERR	ERR
40	Trichloroethane, 1,1,2-	0	0	ERR	ERR	ERR	ERR
41	Trichloroethene	0	0	ERR	ERR	ERR	ERR
42	Vinyl acetate	0	0	ERR	ERR	ERR	ERR
43	Vinyl chloride	0	0	ERR	ERR	ERR	ERR
44	Xylenes (total)	0	0	ERR	ERR	ERR	ERR
45	Bis(2-ethylhexyl)phthal	0	0	ERR	ERR	ERR	ERR
46	Di-n-butylphthalate	0	0	ERR	ERR	ERR	ERR

DATA STATISTICS

DATE: 09/18/92
FILENAM SD_STAT

EXPOSURE POINT: TARGET POND
MEDIUM: SEDIMENT
UNITS: MG/KG
U MULTIPLIER: 0.5

	CHEMICAL	EPC HITS	EPC TOTAL	MAX HIT	MIN VALUE	ARITH MEAN	AM95
1	Aluminum	21	21	3.4E+04	1.2E+04	2.0E+04	2.2E+04
2	Antimony	0	7	ERR	6.3E+00	1.1E+01	1.4E+01
3	Arsenic	7	7	8.7E+00	1.2E+00	4.1E+00	5.4E+00
4	Barium	7	7	2.7E+02	1.0E+02	1.8E+02	2.3E+02
5	Beryllium	4	7	1.9E+00	3.9E-01	9.2E-01	1.3E+00
6	Cadmium	4	7	6.0E+00	1.5E+00	2.9E+00	4.1E+00
7	Calcium	7	7	3.5E+04	7.7E+03	1.5E+04	2.2E+04
8	Chromium	21	21	2.4E+03	1.7E+01	3.6E+02	6.0E+02
9	Cobalt	6	7	1.2E+01	4.1E+00	7.2E+00	8.9E+00
10	Copper	20	21	1.7E+04	1.4E+00	2.0E+03	3.6E+03
11	Iron	7	7	2.2E+04	1.5E+04	1.8E+04	2.0E+04
12	Lead	7	7	1.4E+02	1.1E+01	6.2E+01	9.8E+01
13	Magnesium	7	7	2.5E+04	4.1E+03	7.6E+03	1.3E+04
14	Manganese	7	7	2.3E+02	5.3E+01	1.6E+02	2.0E+02
15	Mercury	1	7	7.3E-01	5.3E-02	3.1E-01	4.9E-01
16	Nickel	21	21	4.2E+01	7.3E+00	2.4E+01	2.7E+01
17	Potassium	7	7	2.5E+03	1.5E+03	1.9E+03	2.1E+03
18	Selenium	1	7	6.5E-01	1.3E-01	7.7E+00	1.3E+01
19	Silver	1	21	4.8E+00	1.1E+00	1.8E+00	2.1E+00
20	Sodium	4	7	1.5E+03	4.7E+02	8.7E+02	1.1E+03
21	Vanadium	7	7	4.4E+01	2.7E+01	3.6E+01	4.0E+01
22	Zinc	21	21	1.2E+03	4.1E+01	2.2E+02	3.5E+02
23	Cyanide	0	3	ERR	3.1E-01	4.1E-01	5.7E-01
24	Ammonia-N	0	0	ERR	ERR	ERR	ERR
25	Nitrate + Nitrite	0	0	ERR	ERR	ERR	ERR
26	Acetone	0	0	ERR	ERR	ERR	ERR
27	Bromodichloromethan	0	0	ERR	ERR	ERR	ERR
28	Butanone, 2-	0	0	ERR	ERR	ERR	ERR
29	Chlorobenzene	0	0	ERR	ERR	ERR	ERR
30	Chloroform	0	0	ERR	ERR	ERR	ERR
31	Dichloroethane, 1,1-	0	0	ERR	ERR	ERR	ERR
32	Dichloroethene, 1,2- (t	0	0	ERR	ERR	ERR	ERR
33	Ethylbenzene	0	0	ERR	ERR	ERR	ERR
34	Methyl-2-pentanone, 4-	0	0	ERR	ERR	ERR	ERR
35	Methylene chloride	0	0	ERR	ERR	ERR	ERR
36	Tetrachloroethane, 1,1,	0	0	ERR	ERR	ERR	ERR
37	Tetrachloroethene	0	0	ERR	ERR	ERR	ERR
38	Toluene	0	0	ERR	ERR	ERR	ERR
39	Trichloroethane, 1,1,1-	0	0	ERR	ERR	ERR	ERR
40	Trichloroethane, 1,1,2-	0	0	ERR	ERR	ERR	ERR
41	Trichloroethene	0	0	ERR	ERR	ERR	ERR
42	Vinyl acetate	0	0	ERR	ERR	ERR	ERR
43	Vinyl chloride	0	0	ERR	ERR	ERR	ERR
44	Xylenes (total)	0	0	ERR	ERR	ERR	ERR
45	Bis(2-ethylhexyl)phthal	0	0	ERR	ERR	ERR	ERR
46	Di-n-butylphthalate	0	0	ERR	ERR	ERR	ERR

DATA STATISTICS

DATE: 09/18/92
FILENAM WW_STAT

EXPOSURE POINT: WATERBURY LAKE
MEDIUM: SURFACE WATER
UNITS: MG/L
U MULTIPLIER: 0.5

	CHEMICAL	EPC HITS	EPC TOTAL	MAX HIT	MIN VALUE	ARITH MEAN	AM95
1	Aluminum	0	2	ERR	4.3E-02	4.3E-02	4.3E-02
2	Chromium	0	2	ERR	3.5E-03	3.5E-03	3.5E-03
3	Copper	0	2	ERR	5.0E-03	5.0E-03	5.0E-03
4	Nickel	1	2	1.4E-01	6.1E-02	1.0E-01	3.6E-01
5	Silver	1	2	9.2E-03	4.5E-03	6.9E-03	2.2E-02
6	Zinc	0	2	ERR	3.0E-03	3.9E-03	9.2E-03
7	Nitrate + Nitrite	0	1	ERR	2.5E-02	2.5E-02	ERR

DATA STATISTICS

DATE: 09/18/92
FILENAM WD_STAT

EXPOSURE POINT: WATERBURY LAKE
MEDIUM: SEDIMENT
UNITS: MG/KG
U MULTIPLIER: 0.5

	CHEMICAL	EPC HITS	EPC TOTAL	MAX HIT	MIN VALUE	ARITH MEAN	AM95
1	Aluminum	2	2	6.8E+03	1.4E+03	4.1E+03	2.1E+04
2	Chromium	1	2	5.2E+01	3.7E+00	2.8E+01	1.8E+02
3	Copper	1	2	4.9E+02	5.2E+00	2.5E+02	1.8E+03
4	Nickel	1	2	2.8E+01	1.1E+01	2.0E+01	7.4E+01
5	Silver	0	2	ERR	4.7E+00	6.8E+00	2.0E+01
6	Zinc	2	2	7.6E+01	5.7E+01	6.6E+01	1.3E+02

APPENDIX 2

ECOTOXICITY SUMMARIES

Aluminum

The toxicology of aluminum in aquatic systems is complex due to variations in its solubility as a function of pH and because of the associations aluminum forms with a variety of ions. The most toxic forms of aluminum appear to be the soluble inorganic forms (USEPA 1986).

The acute toxicity of aluminum to aquatic invertebrate species occurs in much the same range as its toxicity to freshwater fish. Lethal concentrations (LC_{50}) for aluminum (as aluminum chloride) range from 23,000 to about 55,000 µg/L for aquatic invertebrates and 22,000 to 79,000 µg/L for insect larvae. Fathead minnows, juvenile salmon, juvenile channel catfish, juvenile sunfish and juvenile yellow perch showed relatively similar sensitivity to aluminum with LC_{50} or EC_{50} values ranging from 20,000 to 50,000 µg/L. However, certain freshwater fish are more sensitive to the effects of aluminum. The LC_{50} values for the brook trout, rainbow trout and common carp ranging from 3,600 µg/L to 5,200 µg/L (USEPA 1986).

The chronic toxicity of aluminum has been measured in Daphnia magna and the fathead minnow. The chronic toxicity value for D. magna is 1,388 and 1,400 µg/L following 28 or 21 days of exposure to aluminum sulfate, respectively. The chronic toxicity value for the fathead minnow is 5,777 µg/L.

Sublethal effects from chronic exposure to aluminum have been observed in reproductive and developmental parameters in freshwater aquatic organisms. Reduction in reproductive potential has been observed in D. magna following a 21-day exposure to 320 µg/L (USEPA 1986). Exposure to 7,100 µg/L throughout embryonic development and 28 days after hatching had a significant effect on weight and length of hatchlings. Exposure to 9,200 µg/L significantly affected the survival of these juvenile forms (USEPA 1986).

The aquatic plants most sensitive to aluminum exposure are the single-cell algae. Growth in both diatoms and the green alga Selenastrum capricornutum is inhibited at aluminum concentrations ranging from 460 to 990 µg/L, reduced cell counts were observed in the green alga at concentrations of 990 to 1,320 µg/L, and lethality occurred at 6,480 µg/L in the diatom. Duckweed is less sensitive to the effects of aluminum exposure with adverse effects (reduction in frond production) occurring at aluminum concentrations in excess of 45,000 µg/L (USEPA 1986).

The USEPA has proposed draft ambient water quality criteria for protection of freshwater aquatic life of 150 µg/L (chronic) and 950 µg/L (acute) (USEPA 1986).

No bioaccumulation data were located for aluminum.

Reference:

USEPA. 1986. U.S. Environmental Protection Agency. Office of Research and Development. Ambient water quality criteria document for aluminum. (draft). Washington, DC: U.S. Environmental Protection Agency.

Cadmium

The acute toxicity of cadmium to freshwater organisms ranges from 1.0 to 73,500 μg/L for fish and from 3.5 to 28,000 μg/L for invertebrates. Cladocerans are the most sensitive invertebrates with toxicity values (LC_{50}) of about 30 to 60 μg/L. Rotifers are somewhat more resistant with acute LC_{50} values of 200 to 500 μg/L. Mayflies and stoneflies are the most resistant with acute LC_{50} values of about 20,000 μg/L. Cadmium toxicity in fish varies greatly among species with salmon, rainbow trout and brook trout having acute LC_{50} values of 1 to about 29 μg/L and goldfish, fathead minnows and sunfish having LC_{50} values between 2,100 and 66,000 μg/L (USEPA 1980).

Waterfowl are relatively resistant to short-term exposure to cadmium (Eisler 1985). Ducks produce large amounts of metallothioneins which bind heavy metals, thus reducing cadmium's toxicity potential (Brown et al. 1977).

Chronic effects have been observed in mallard ducklings fed 20 ppm dietary cadmium for 12 weeks, including disruption of blood chemistry and development of kidney lesions (Cain et al. 1983). Behavioral effects in young American black ducks, have been associated with 4 ppm dietary cadmium fed to parents. Symptoms included hyperresponsiveness and altered avoidance behavior (Heinz and Haseltine 1983).

The potential for bioaccumulation of cadmium is high. A diet of 200 ppm cadmium for 13 weeks resulted in accumulations in both the liver (110 ppm fresh weight (FW)) and kidney (134 ppm FW) of drake mallards (White and Finley 1978). Similarly, 20 ppm dietary cadmium for 12 weeks produced concentrations of 42 ppm in the liver of mallard ducklings (Cain et al. 1983).

Spehar et al. (1978) reported a whole body bioconcentration factor of 1,750 for Physa in a 28-day exposure. Bioconcentration factors for cadmium in freshwater fish range from 3 for brook trout muscle to 12,400 for mosquitofish (whole body) (USEPA 1980).

The primary adverse effect on freshwater plants from cadmium exposure is growth reduction. Growth reduction occurred in diatoms and green algae (Chlorella and Selanastrum spp.) at cadmium concentrations ranging from 2 to 250 μg/L. Reduction in frond number occurred in freshwater ferns and duckweed at 10 μg/L (USEPA 1980).

References:

Brown DA, Bawden CA, Chatel KW, Parsons TR. 1977. The wildlife community of Iona Island jetty, Vancouver, BC, and heavy metal pollution effects. Environ. Conserv. 4:213-216.

Cain BW, Sileo L, Frarson JC, Moore J. 1983. Effects of dietary cadmium on mallard ducklings. Environ. Res. 32:286-297.

Eisler R. 1985. Cadmium effects to fish, wildlife and invertebrates: A synoptic review. U.S. Fish and Wild. Serv. Biol. Rep. 85(1.2)

Heinz GH, Haseltine SD. 1983. Altered avoidance behavior of young black ducks fed cadmium. Environ. Toxicol. Chem. 2:419-421.

Spehar RL et al. 1978. Toxicity and bioaccumulation of cadmium and lead in aquatic invertebrates. Environ. Pollut. 15:195.

USEPA. 1980. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for cadmium. PB81-117368.

Chromium

Aquatic species are sensitive to both valence states of chromium, Cr(III) (trivalent) and Cr(VI) (hexavalent). For trivalent chromium, toxicity is greater in soft water than in hard water. In soft water, LC_{50} values for Cr(III) range from 2,000 μg/L (mayfly) to 64,000 μg/L (caddisfly) (USEPA 1984). In fish, LC_{50} values range from 3,300 μg/L (guppy, soft water) to 71,900 μg/L (bluegill, hard water). Chronic values of 1,000 μg/L (fathead minnow) and 66 μg/L (Daphnia) were reported in life cycle tests. A concentration of 9,900 μg/L inhibited root growth in one freshwater plant species.

For Cr(VI), acute aquatic data indicate that invertebrate species are more sensitive than most fish (USEPA 1984a, Eisler 1986). An amphipod crustacean was the most acutely sensitive (67 μg/L). Chronic toxicity values for trout were 265 μg/L and 1,900 μg/L for the fathead minnow. Hexavalent chromium has been reported to reduce growth in salmon (at 16 μg/L) and reduce life span and fecundity in Daphnia (10 μg/L).

References:

Eisler R. 1986. Chromium hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Laurel, MD: U.S. Department of the Interior.

USEPA. 1984. U.S. Environmental Protection Agency. Ambient water quality criteria for chromium. Washington, DC: U.S. Environmental Protection Agency. EPA 440/5-84-029.

Copper

Both aquatic invertebrates and fish are sensitive to the toxic effects of copper. The toxicity of copper to aquatic organisms is affected by various environmental conditions. Copper toxicity decreases as the hardness of the water increases. Total organic carbon also reduces copper toxicity, probably due to complexation. Acute values in hard water range from 6.5 μg/L for Daphnia magna to 10,200 μg/L for the bluegill. Among benthic invertebrates, Physa spp. (snails) are very sensitive to copper concentrations greater than 35 μg/L (USEPA 1985). Sediment copper concentrations greater than 681 mg/kg inhibit or are lethal to a variety of freshwater invertebrates (Cairns et al. 1984, Malveg et al. 1984). Insects are more resistant to the toxic effects of copper than are some of the other invertebrate species.

The chronic toxicity values for freshwater species range from 3.9 μg/L for brook trout to 60 μg/L for northern pike (USEPA 1985). Concentrations as low as 6.1 μg/L cause chronic toxicity in some invertebrates and as low as 3.9 μg/L cause toxicity in some fish species. Among coldwater fish, salmon and trout displayed adverse effects at copper concentrations as low as 4 μg/L. Warmwater fish are generally one to three orders of magnitude more resistant than salmonids. An acute toxicity of 42.5 μg/L of copper for rainbow trout at a water hardness of 50 mg/L has been reported (USEPA 1985). Acutely toxic effects of copper in bluegill sunfish occur at copper concentrations greater than 1,000 μg/L at 50 mg/L hardness. The bioconcentration factor for copper in bluegill is zero (USEPA 1985).

In a study by McKim et al. (1978) copper concentrations of 23.0 and 20.8 μg/L (water hardness of 44.5 mg $CaCO_3$) had no effect on early-eyed and late-eyed brown trout embryos, respectively. Significant chronic toxicity, however, was noted at 46.5 μg/L and 43.8 μg/L for each embryo classification. It is expected that acute toxicity to brown trout would occur at copper concentrations considerably greater than the above chronic toxicity values.

Copper toxicity and inhibitory effects towards aquatic plants are well known (USEPA 1985). Some plants excrete chelating agents to lower the concentration of the cupric ion, the biologically active species.

Although no information was available on toxic effects in wildlife, copper toxicity has been demonstrated in sheep and swine. Acute poisoning occurs in sheep at a dose of approximately 200 mg/kg (Clement Associates 1985). Copper salts act directly on the gastrointestinal tract causing gastroenteritis, shock and death. Chronic exposure to excess copper causes absorption and accumulation of copper in the liver (Clement Associates 1985). A sudden, acute hemolytic crisis may develop under these exposure conditions. A copper intake of 1.5 g/day over a period of 30 days is fatal in many breeds of sheep (Clement Associates 1985).

A dietary dose of 250 mg/kg copper causes toxicosis with hypochromic microcytic anemia, jaundice and marked increases in liver and serum copper levels in swine, unless zinc and iron levels are increased (Clement Associates 1985). Once removed from the diet, copper is rapidly eliminated in swine (Clement Associates 1985).

References:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

Cairns MA, Nebeker AV, Gakstatter JA, Griffis WL. 1984. Toxicity of copper-spiked sedimenters to freshwater invertebrates. Environ. Toxicol. Chem. 3:435-445.

Malveg KW, Schuytema GS, Gaksratter JH, Krawczyk DF. 1984. Toxicity of sediments from three metal-contaminated areas. Environ. Toxicol. Chem. 3:279-291.

McKim JM, Eaton JG, Holcombe GW. 1978. Metal toxicity to embryos and larvae of eight freshwater fish - II: Copper. Bull. Environ. Contam. Toxicol. 19:608-616.

USEPA. 1985. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for copper. Washington, DC: U.S. Environmental Protection Agency. EPA 440/5-84-031.

Cyanide

Cyanide includes hydrogen cyanide and its salts. Hydrogen cyanide and simple cyanide salts are highly toxic by all routes (Clement Associates 1985). The toxic effect of cyanide is due to inhibition of the electron transport system in oxidative phosphorylation, which makes it acutely toxic to most forms of life. It also produces chromosome breaks in the bean plant, Vicia fabae (Clement Associates 1985). Livestock death has been reported from exposure to high levels of cyanide leaching from a drum disposal site (Clement Associates 1985).

No data were located regarding the effects of cyanide on terrestrial wildlife. Studies in laboratory animals have indicated that the acute toxicity of cyanide varies between species. The acute oral LD_{50} for potassium cyanide is 4 mg CN^-/kg in rats and 3.4 mg CN^-/kg in mice (USEPA 1987). A dose equal to the LD_{50} in mice had only minimal effects on guinea pigs (USEPA 1987).

Animal studies have reported toxic effects of chronic cyanide exposure in several species. Weanling rats fed a diet providing about 30 mg CN^-/kg/day for 11.5 months had significantly reduced body weight gain, decreased thyroxin secretion rates and spinal cord degeneration (USEPA 1987).

Pigs fed diets containing 30.3, 276.6 or 520.7 mg CN^-/kg diet throughout gestation and lactation showed histopathological changes in kidney and thyroid gland. Dogs dosed with a capsule containing about 0.27 mg CN^-/kg-bw once a day for 16 months had degenerative changes in ganglion cells of the central nervous systems; however, rats fed a diet which provided about 3.6 to 10.8 mg CN^-/kg bw/day showed no clinical or histological effects. Increased thiocyanate levels were noted in blood and tissue samples (USEPA 1987).

Acute toxicity for cyanide have been established for a wide variety of freshwater species and at exposure concentrations that range from 44.7 μg/L to 2,490 μg/L (USEPA 1985). Invertebrates are considerably more resistant than are fishes, although some invertebrates such as Daphnia and Gammarus pseudolimnaeus are similar in sensitivity to the fishes. All of the species with acute values above 400 μg/L are invertebrates. The toxicity of cyanide to fishes is dependent upon the life-stage of the fish and also upon environmental factors such as dissolved oxygen concentration. Embryos, sac fry and warmwater species appear to be the most resistant tot he toxic effects of cyanide. Juvenile fish of the species most sensitive to cyanide are killed by exposure to free cyanide concentrations in excess of 50 μg/L. Fish are more sensitive to the lethal effects of cyanide when in waters with dissolved oxygen concentrations below the saturation level (USEPA 1984).

The chronic toxicity of cyanide to aquatic animals has been demonstrated by the reduced survival and growth in various freshwater fish exposed to between 20 and 50 $\mu g/L$ free cyanide. Reductions in survival (bluegill) and reproduction (brook trout and fathead minnow) have also been observed as the result of exposure to free cyanide at levels between 1.8 and 16.4 $\mu g/L$.

The toxicity of cyanide to aquatic plants has been demonstrated in a range of species. Freshwater plants showed toxic effects ranging from death, inhibition and decreased root growth at cyanide concentrations ranging from 30 to 26,000 $\mu g/L$ (USEPA 1985).

References:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

USEPA. 1987. U.S. Environmental Protection Agency. Office of Drinking Water. Cyanide health advisory. Washington, DC: U.S. Environmental Protection Agency. March 31.

USEPA. 1985. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Quality criteria for water 1985. Washington, DC: U.S. Environmental Protection Agency. PB85-227460.

USEPA. 1984. U.S. Environmental Protection Agency. Office of Health and Environmental Assessment. Health effects assessment for cyanide. Washington, DC: U.S. Environmental Protection Agency. EPA/540/1-86-011.

<u>Lead</u>

Lead has no known essential or beneficial function in living organisms, and its toxic effects have been well documented in aquatic organisms. Comparatively high concentrations (greater than 500 $\mu g/L$) of lead are necessary to adversely affect aquatic plants or amphibians (Taylor et al. 1990, USEPA 1985). Cladocerans, snails and rainbow trout display chronic effects from exposure to 9 to 13 $\mu g/L$. Species vary greatly in their response to the effects from acute exposure to lead with lethality (LC_{50}) in daphnids at 600 to 900 $\mu g/L$, midges at 224,000 $\mu g/L$ and lethality occurred in fish at exposure concentrations ranging from about 4,000 $\mu g/L$ (brook trout) to about 400,000 $\mu g/L$ (bluegill and fathead minnow) (USEPA 1985).

Adverse effects of chronic lead exposure have been observed in daphnids (decreased reproduction) at 1 $\mu g/L$ and rainbow trout (anemia) at 10-13 $\mu g/L$. Signs of lead toxicity in fish include spinal curvature, decreased mobility, caudal fin degeneration, destruction of respiratory epithelium and widespread enzyme abnormalities.

Excessive lead exposure to plants causes reduced photosynthesis, cell division and water uptake. Growth in freshwater algae is inhibited at 5.0 μg/L and concentrations in excess of 4,000 μg/L were lethal. Bioconcentration factors for lead in algae range from 20 (3-hour exposure to 1,000 μg/L) to 92,000 (28-day exposure to 5 μg/L) (Eisler 1988).

With the exception of some alkyl lead compounds, lead poisoning through bioaccumulation is not believed to occur (Eisler 1988). Chronic and acute lead toxicity in birds varies according to species, age and chemical form of lead ingested. Young birds are more sensitive to lead poisoning than adults (Hoffman et al. 1985).

References:

Eisler R. 1988. Lead hazards to fish, wildlife and invertebrates: A synoptic review. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Laurel, MD: U.S. Department of the Interior.

Hoffman DJ., Franson, JC, Pattee OH, Bunck CM, Anderson A. 1985. Survival, growth and accumulation of ingested lead in nestling American kestrels (Falco sparverius). Arch. Environ. Contam. Toxicol. 14:89-94.

Taylor DH, Steele CW, Strickler-Shaw S. 1990. Responses of green frog (Rana clamitans) tadpoles to lead-polluted water. Environ. Toxicol. Chem. 9:87-93.

USEPA. 1985. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for lead. Washington, DC: U.S. Environmental Protection Agency. PB85-227437.

Mercury

Mercury occurs in inorganic and organic forms, the organic forms generally showing greater toxicity. Methylmercury causes embryotoxicity and teratogenicity in a variety of experimental animals (Clement Associates 1985). Experimental animals exposed to organic mercury compounds experience toxic effects in the gonads, heart, liver, pancreas and gastrointestinal tract. The endocrine, immunocompetent and central nervous systems are also involved (Clement Associates 1985).

Oral LD_{50} values for soluble mercuric salts range from 20 to 60 mg/kg (Clement Associates 1985). Mercuric chloride causes teratogenicity. Mercurous compounds are less toxic by the oral route. Chronic exposure to inorganic mercury compounds affects the central nervous system causing behavioral and neurological disturbances (Clement Associates 1985).

Reference:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

Nickel

In freshwater, toxicity depends on hardness; nickel tends to be more toxic in softer water. Acute values for exposure to a variety of nickel salts, expressed as nickel, range from 510 μg/L for Daphnia magna to 46,200 μg/L for the banded killifish at comparable hardness levels. Chronic values range from 14.8 μg/L for the Daphnia magna in soft water to 530 μg/L for the fathead minnow in hard water. Acute-chronic ratios for Daphnia magna range from 14 in hard water to 83 in soft water, and are approximately 50 in both hard and soft water for the fathead minnow. Residue data for the fathead minnow indicate a bioconcentration factor of 61. Freshwater algae experience reduced growth at nickel concentrations as low as 100 μg/L (USEPA 1980).

Toxicity of nickel to aquatic organisms depends on water hardness, with higher toxicity in softer water. Acute toxicity ranges from 510 μg/L for Daphnia magna to 46,200 μg/L for the banded killifish at similar hardness levels (Clement Associates 1985). Chronic toxicity is also highly variable, with a chronic value of 14.8 μg/L for Daphnia magna in soft water and 530 μg/L for the fathead minnow in hard water (Clement Associates 1985). Exposure to nickel reduces growth at concentrations as low as 100 μg/L (Clement Associates 1985). The ER-L for nickel is 30 mg/kg (Long and Morgan 1991).

Federal AWQC are available for nickel for protection of freshwater aquatic life. The criteria are a function of water hardness, as follows:

$$AWQCc\ (Ni) = \exp\ (0.846 \times (\ln \text{hardness}) + 1.1645) \quad (1)$$

$$AWQCa\ (Ni) = \exp\ (0.846 \times (\ln \text{hardness}) + 3.3612) \quad (2)$$

where:

AWQCc (Ni)	=	Chronic (4-day average) AWQC for nickel (μg/L)
AWQCa (Ni)	=	Acute (1-hour average) AWQC for nickel (μg/L)
exp	=	Exponential (base e)
hardness	=	Calcium carbonate hardness (mg/L $CaCO_3$)
ln	=	Natural logarithm

References:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

Long ER, Morgan LG. 1991. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. Seattle, WA: National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NOS OMA 52.

USEPA. 1980. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for nickel. EPA 440/5-80-060.

Silver

Excess silver in the diet of dogs, sheep, pigs, chicks, turkey poults and ducklings induces selenium, vitamin E and copper deficiency symptoms, even though these nutrients are adequate in the diet, silver can aggravate symptoms if one or more of these nutrients is below required levels in the diet (Clement Associates 1985).

Silver is acutely toxic to aquatic life. Freshwater species mean acute values (SMAVs) range from 0.9 µg/L for the waterflea Daphnia magna to 560 µg/L for the crustacean Orconectes immunis (USEPA 1987). Acute toxicity among the most sensitive species occurs over a small range, with a genus mean acute value that ranges from 2.2 to 29 µg/L. While arthropods are most sensitive, freshwater fish are almost as sensitive, with SMAVs that range from 8.2 µg/L for Rhinichthys osculus to 13 µg/L for Lepomis macrochirus (USEPA 1987).

Chronic toxicity occurs in cladocera at levels that range from less than 0.56 µg/L to 28.6 µg/L (USEPA 1987). Chronic values for fish range from 0.12 µg/L for rainbow trout (Salmo gairdneri) to 0.49 µg/L for the fathead minnow (Pimephales promelas).

Freshwater algae are more sensitive to silver than aquatic vascular plants. The 96-hr EC50 for chlorophyll a production in the alga Selenastrum capricornutum exposed to silver is 2.6 µg/L. Tests involving vascular plants indicate the EC_{50} is in the range 270 µg/L (Lemna minor) to 7,500 µg/L (Elodea canadensis) (USEPA 1987).

Reference:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical, and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

USEPA 1987. U.S. Environmental Protection Agency. Ambient aquatic life water quality criteria for silver. Draft. Narragansett, RI: U.S. Environmental Protection Agency. September 1987.

Trichloroethene

Only limited data were located regarding the toxicity of trichloroethene (TCE) to aquatic organisms. Acute toxicity has been demonstrated in Daphnia magna (48-hour LC_{50} = 85,000 µg/L), fathead minnow (48-hour LC_{50} = 40,000 to 70,000 µg/L) and bluegill (96-hour LC_{50} = 45,000 µg/L) (USEPA 1980).

Sublethal exposure to TCE causes loss of equilibrium in 50% of exposed fathead minnows (96-hour LC_{50} = 21,900 µg/L). Similar effects, including erratic swimming, uncontrolled movements and loss of equilibrium, have also been observed in salt water species (grass shrimp and sheepshead minnow) following a few minutes exposure to TCE (USEPA 1980). No data were located regarding the chronic toxicity of TCE to aquatic organisms.

There are only limited data available regarding the bioconcentration potential of TCE in aquatic organisms. The half-life of TCE in bluegill (whole-body) has been measured at 1-day, with a bioconcentration factor of 17 (USEPA 1980). No data were located regarding the toxicity or bioaccumulation of TCE to freshwater plant species.

No data were located regarding the toxicity of TCE to terrestrial wildlife. Laboratory investigations have shown that TCE is minimally toxic by the oral and inhalation routes. Inhalation LC_{50}'s in rats and mice range from 7,500 to 50,000 ppm. Oral LD_{50}'s range from about 6,000 mg/kg for dogs and cats to approximately 2,300 mg/kg for mice (ATSDR 1988).

The principal toxic effects observed in rats and mice following subchronic (15 to 365 days) exposure to TCE by the inhalation (100 ppm) or oral (100 mg/kg) routes are to the bone marrow, central nervous system, liver and kidney. Subchronic inhalation exposure to 55 ppm resulted in increased liver weight in rats, although 35 ppm caused no observable injury to rats, rabbits, guinea pigs, monkeys or dogs (ATSDR 1988). Dermatological reactions have been reported in animals exposed chronically at levels greater than 2,000 mg/m_3 for six months (Clement Associates 1985).

Trichloroethene is mutagenic in several microbial assay systems (Clement Associates 1985). Oral administration of TCE produces hepatocellular carcinomas in mice. Reproductive toxicity and teratogenicity do not appear to be a concern related to TCE exposure Clement Associates 1985).

References:

ATSDR. 1988. Agency for Toxic Substances and Disease Registry. Toxicological profile for trichloroethylene. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

USEPA. 1986. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Quality criteria for water 1986. Washington, DC: U.S. Environmental Protection Agency. EPA 440/5-86-001).

USEPA. 1980. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for trichlorethylene. Washington, DC: U.S. Environmental Protection Agency. NTIS Document No. PB81-117871.

<u>Zinc</u>

Aquatic invertebrates are very resistant to toxic effects of zinc compared with the toxicities of copper and cadmium. Acute toxicity values for the fathead minnow and bluegill are approximately 4,000 μg/L and 6,000 μg/L, respectively, at 50 mg/L water hardness (USEPA 1987). Malformations of frog embryos have been associated with zinc concentrations of 2,200-3,600 μg/L

(Dawson et al. 1988). Physa spp. (snails) exhibit acutely toxic effects at zinc concentrations greater than 1,000 µg/L at 50 mg/L water hardness (USEPA 1987). Zinc toxicity to aquatic species is reduced by increased water hardness.

Chronic zinc toxicity to fish and aquatic invertebrates has been demonstrated at concentrations of 36.4 µg/L and 46.7 µg/L, respectively. Comparable acute toxicity values are 66 µg/L (fish) and 32 µg/L (invertebrates).

Zinc concentrations less than 100 µg/L are toxic to some algal species (USEPA 1987).

It is an essential element required for protein synthesis, enzyme function and carbohydrate metabolism (Clement Associates 1985). However, growth retardation, hypochromic anemia and defective mineralization of bone occurred in rats fed a diet containing 0.25% zinc (Clement Associates 1985). Excessive intake of zinc may cause deficiency of copper and result in anemia, even though copper is adequate in the diet (Clement Associates 1985).

Zinc may be necessary for the growth of tumors in animals exposed to carcinogens. Tumor growth is slower in zinc-deficient laboratory animals, although animals may be more susceptible to induction of cancer.

The ER-L for zinc in sediment is 120 mg/kg (Long and Morgan 1991). Acute toxicity in freshwater organisms occurs over concentrations that range from 90 to 58,100 µg/L (Clement Associates 1985). Chronic toxicity in freshwater organisms has been observed over the range 47 to 852 µg/L. The alga Selanastrum capricornutum exhibited toxic effects at 30 µg/L (Clement Associates 1985).

Federal AWQC are available for zinc for protection of freshwater aquatic life. The criteria are a function of water hardness, as follows:

$$\text{AWQCc (Zn)} = \exp\,(0.8473 \times (\ln \text{hardness}) + 0.7614) \qquad (3)$$

$$\text{AWQCa (Zn)} = \exp\,(0.8473 \times (\ln \text{hardness}) + 0.8604) \qquad (4)$$

where:

AWQCc (Zn)	=	Chronic (4-day average) AWQC for zinc (µg/L)
AWQCa (Zn)	=	Acute (1-hour average) AWQC for zinc (µg/L)
exp	=	Exponential (base e)
hardness	=	Calcium carbonate hardness (mg/L $CaCO_3$)
ln	=	Natural logarithm

References:

Clement Associates. 1985. Clement Associates, Inc. Chemical, physical and biological properties of compounds present at hazardous waste sites. Final Report. Arlington, VA: Clement Associates, Inc.

Dawson DA, Stebler EF, Burks SL, Bantle JA. 1988. Evaluation of the developmental toxicity of metal-contaminated sediments using short-term fathead minnow and frog embryo-larval assays. Environ. Toxicol. Chem. 7:27-34.

Long ER, Morgan LG. 1991. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. Seattle, WA: National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NOS OMA 52.

USEPA. 1987. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Ambient water quality criteria for zinc. Washington, DC: U.S. Environmental Protection Agency. PB85-227023.